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On the occurrence of turquoise in Cornwall.

By Sir Arthur Russell, Bart.

With a chemical analysis by E. A. Vincent, Ph.D., A.R.I.C., F.G.S.

[Read January 24, 1952.]

In my description of the mineral rashleighite, which was given in this magazine in 1948,[1] I mentioned that most of the mineral from the Bunny mine, St. Austell, was in colour light blue-green, but that it was also sometimes true turquoise-blue. Likewise, at the Castle-an-Dinas wolfram mine, St. Columb Major, there occurred rarely in addition to the blue-green rashleighite a true turquoise-blue mineral which was first assumed to be turquoise[2] and later rashleighite. It has now been found, however, that this turquoise-blue mineral is in fact true turquoise, and distinct from the green rashleighite.[2] Specimens of this turquoise were found at the Bunny mine, associated with varlamoffite.[3]

I have since found much larger and better specimens at the Gunheath china-clay pit, St. Austell (six-inch ordnance map, Cornwall, 41 SE., 1908), which lies some 670 yards south-west of Bunny mine. Traversing almost the full length of the pit is a very remarkable lode having a north-east and south-west direction, and being almost certainly a continuation of one of the Bunny mine lodes. A year or two back, this lode was even better exposed than at present (1951), the working of the pit having caused the upper portion to crumble away; even now, however, it is a striking object owing to the china-clay ground on either side of it having been washed away by the monitors. It

[1] A. Russell, On rashleighite, a new mineral from Cornwall, intermediate between turquoise and chalcosiderite. Min. Mag., 1948, vol. 28, pp. 356 and 357.

[2] M. H. Hey and F. A. Bannister, Russellite, a new British mineral. With a note on the occurrence and the accompanying minerals, by Arthur Russell. Min. Mag., 1938, vol. 25, p. 54.

[3] The occurrence of turquoise at Bunny mine was mentioned in a joint paper by myself and Dr. Vincent, On the occurrence of varlamoffite in Cornwall. Min. Mag., 1952, vol. 29, p. 819.

appears as a jagged wall of rudely crystallized greyish translucent quartz with somewhat comby structure, traversing the kaolinized granite, the width varying from 12 to 15 feet, but apparently thinning out at the south-west end of the pit.

Between the ribs of quartz there are in places both thin layers and thick impersistent bands of compact turquoise, the latter up to 7 cm. in thickness, which present a beautifully blue colour, especially when wet. In the open parts of the lode are considerable cavities lined with prismatic crystals of quartz covered with a layer of turquoise upon which are crusts of minute colourless or white needles and larger bladed crystals of wavellite, the remainder of the cavities being filled with white china-clay. Other specimens are remarkable in consisting of large masses of opaque white prismatic crystals of quartz cemented together by turquoise, these crystals when broken out leaving blue smooth prismatic casts. The turquoise also forms patches and veinlets in deep brownish vinaceous granular aggregates of cellular crystalline quartz.

There also occur large masses of turquoise presenting somewhat rounded surfaces and occasionally distinctly mamillary in form, and penetrated here and there by grey prisms of quartz, which in section show an outer secondary arrangement of small malformed crystals. These masses are often of a very pale blue to almost white colour from admixture with kaolinite, and are soft, being easily scratched even with the finger nail. The only other minerals observed in this lode are tourmaline and gilbertite, small needle brushes of the former rendering the quartz grey. Neither cassiterite nor wolframite appear to be present.

In the north-western end of the pit there appears to be another parallel lode similar in content, but this is at present obscured by loose material. Turquoise occurs in the debris and here I found a single thin sheet of native copper ($7\frac{1}{2} \times 4\frac{1}{2}$ cm.), this being the only metallic mineral I have observed in either lode: it is interesting as indicating a possible source of copper in the turquoise.

In the Hensbarrow china-clay pit, midway between Bunny mine and Gunheath, turquoise also occurs with thin layers of wavellite, but in much smaller quantity. It is derived from a lode at present not well exposed, but certainly identical with one of those of Bunny and Gunheath.

In thin section under the microscope the turquoise appears as a uniformly fine-grained aggregate of tiny acicular crystals, containing, as the analysis shows, even in the purest material a good deal of admixed kaolinite and an occasional small grain of quartz. Small cavities have

a mamillary crystalline surface. The specific gravity of the analysed material is 2·69–2·70.

The material polishes well, the colour being enhanced and yielding beautiful specimens. It is, however, difficult to obtain large uniform surfaces free from penetration of granular quartz, which in the process of polishing breaks out, leaving small hollows. The largest surface free from quartz which I have had polished measures about 11×5 cm.

The results of an analysis most kindly made by my friend Dr. E. A. Vincent, of the Department of Geology and Mineralogy, Oxford University, are contained in the following table. From this it will be seen that the Gunheath mineral has a composition very similar to that of the turquoise from Los Cerillos, New Mexico.

TABLE I. Chemical analyses of turquoise.

	I.	II.	III.	IV.	V.	VI.	VII.
P_2O_5 ...	26·76	—	—	26·76	33·82	34·12	33·72
As_2O_5 ...	trace	—	—	—	—	—	—
Al_2O_3 ...	35·05	—	8·19	26·86	33·94	36·84	32·75
Fe_2O_3 ...	3·22	—	—	3·22	4·07	—	4·28
FeO ...	0·13	—	—	0·13	0·16	—	0·71
CuO ...	7·79	—	—	7·79	9·84	9·57	7·54
CaO ...	n.fd.	—	—	—	—	—	—
MgO ...	n.fd.	—	—	—	—	—	—
SiO_2 ...	10·14	0·50	9·64	—	—	—	2·24
$H_2O^{+105°}$ ...	17·12	—	2·92	14·20	17·94	19·47	18·96
$H_2O^{-105°}$ ...	0·18	—	—	0·18	0·23	—	—
	100·39	0·50	20·75	79·14	100·00	100·00	100·20
Sp. gr. ...	2·69–2·70	—	—	—	—	—	2·697–2·764

I. Impure turquoise, Gunheath, St. Austell, Cornwall. (New analysis.)
II. To subtract for estimated 0·5 % quartz observed in thin section.
III. To subtract, assuming rest of SiO_2 present in kaolinite of theoretical composition $Al_2O_3.2SiO_2.2H_2O$.
IV. Remainder after subtracting II and III.
V. Column IV, recalculated to 100 %, and approximating to composition of turquoise in the mixture.
VI. Composition by weight of turquoise of theoretical composition

$$CuAl_6(PO_4)_4\,(OH)_8.5H_2O.$$

VII. Turquoise, Los Cerillos, New Mexico. H. Jung, Chemie der Erde, 1932, vol. 7, p. 81. [M.A. 5–279.]

In both the Gunheath and Los Cerillos turquoise there is some substitution of aluminium by ferric iron. X-ray powder photographs of the analysed Cornish material and of a fragment of the Los Cerillos turquoise have kindly been taken by Mr. A. W. G. Kingsbury, who reports

that he is unable to detect any difference whatever in the two patterns. The admixed kaolinite and quartz do not appear to have influenced the photograph obtained from the analysed Gunheath material.

The estimated composition of the analysed mixture is thus about 0·5 % quartz, 20·5 % kaolinite, and 79 % turquoise. If the recalculated analysis of the Gunheath turquoise (column V) is recast on a basis of 29 oxygen atoms, to compare with the theoretical composition (column VI) $CuAl_6P_4H_{18}O_{29}$, the following result is obtained:

$$Cu_{1\cdot05}(Al, Fe)_{6\cdot12}P_{4\cdot06}H_{17\cdot24}O_{29}.$$

This seems to be in reasonably satisfactory agreement with the theoretical formula for turquoise.

Textural features of some Bushveld norites.

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[Read March 27, 1952.]

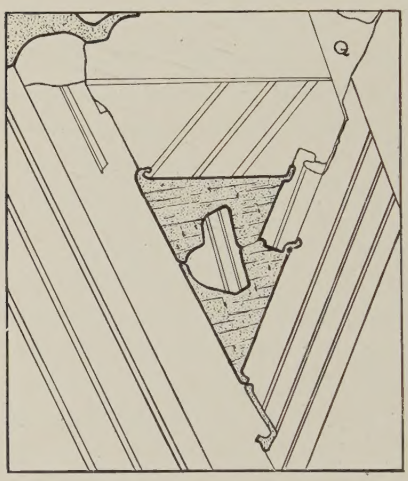
GEOPHYSICAL Laboratory work is especially applicable to quenched rocks, but does not lend itself to the solution of problems connected with the interpretation of structural relationships between the component minerals of deep-seated rocks. The detailed examination of a rock of simple mineral composition might be expected to yield a picture of the way in which phase-boundary adjustments are made in a rock crystallizing under such conditions. Some of the Bushveld basic rocks are of such a nature, and in the present paper an attempt is made to analyse and interpret the structural relationships between the two minerals bronzite and bytownite (An_{78-80}), of which they are composed. The material studied was collected under the guidance of Dr. A. L. Hall during the International Geological Congress in 1929, supplemented by core specimens recently made available through the courtesy of an old student of the College.

The rocks examined are bronzite-anorthosites, leuconorites, mottled anorthosites (Hall), and melanorites. In these rocks bronzite is the dominant pyroxene, and in many, clinopyroxene has the status of a minor accessory only. The bronzite has several different modes of occurrence: it forms large, irregular crystal grains sparsely scattered through the mosaic of plagioclase in some cases; but in others it occurs as closely packed subhedral crystals, with a relatively small content of interstitial plagioclase. Round some of the isolated bronzites, clinopyroxene forms a narrow partial or complete rim, 'insulating' them from the adjacent plagioclases. In some of the norites the pyroxenes are restricted to clots within which bronzite and clinopyroxene are ophitically related to the plagioclase. Finally, in some of the mottled anorthosites similar clots consist of closely packed, rounded bronzites which, together with small plagioclase grains, are poikilitically enclosed within clinopyroxene. Each of these relationships is examined in turn.

1. *The isolated bronzites.*

The relationship between bronzite and plagioclase that is most obvious as regards interpretation is illustrated in fig. 1. The pyroxene is

interstitial to the essentially lath-shaped plagioclase, and occupies angular 'cavities' bounded by crystal-faces of the felspar. It will be noted that in the penultimate stage a little of the pyroxene substance was injected along the inter-crystal boundaries. A little late quartz at the top of the section shows the same phenomenon.



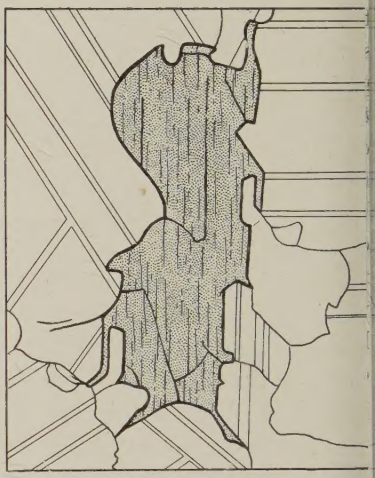


Fig. 1. Fig. 2.

Fig. 1. Bronzite interstitial to bytownite in bronzite-anorthosite: Q = quartz. Width of section, 2 mm.

Fig. 2. Shape features of bronzite isolated in bytownite: simultaneous crystallization of the two minerals. Width of section, 1·5 mm.

Precisely the opposite relationship is encountered in melanorite approaching pyroxenite in composition, and as rich in bronzite as the previous rock is poor. The roles of the two minerals are completely reversed: the bronzites form a self-supporting mesh to which the meagre plagioclase is interstitial. Harker's explanation of a similar variation in the order of crystallization of olivine and anorthite in the allivalites of Rum[1] is presumably applicable to the case in point. As bytownite and bronzite are members of isomorphous series, a cotectic relationship must hold; and whichever of the two is in local excess of the cotectic ratio will crystallize first. It follows from these two extreme cases that there must be rocks in this suite in which the proportions of pyroxene and plagioclase are such as to ensure simultaneous crystallization. With this in mind we pass on to examine the shape-details of the isolated bronzites.

[1] A. Harker, Small Isles of Inverness. Mem. Geol. Surv., 1908, p. 86.

In the pyroxene-poor noritic rocks bronzite forms irregular grains, though sometimes with a semblance of prismatic habit, bounded by a combination of plane and strongly curved surfaces. The plane surfaces are normally crystal-faces of the adjoining plagioclases; but where the contact-surface is appreciably curved, neither mineral is euhedral towards the other. Such curved contact-surfaces are therefore characteristic of simultaneous crystallization. In confirmation of this conclusion it may be stated that in the plagioclase mosaic, which makes up the greater part of the rock, the contact-surfaces are exactly of the same types: curved surfaces predominate, but some are plane. These latter correspond in part to crystal-faces in the zone [(100) (010)] and therefore run parallel to the albite and Carlsbad twin-planes; but others cannot be correlated with actual crystal-faces. It is clear, however, that two crystals of plagioclase growing against one another will meet, other things being equal, in a plane surface. A curved surface will be developed when one crystal is so placed as to be able to exert its pressure of crystallization advantageously against its neighbour. In some grains all the contact surfaces are strongly curved, but so are the adjacent inter-plagioclase boundaries. The grain illustrated in fig. 2 is a little more complicated: the short lengths of straight-line contacts on the right-hand side are parallel to the direction of maximum growth of the bronzite, showing that it was able, within limits, to control its own shape; but on the left-hand side the strongly curved boundary against plagioclase indicates simultaneous growth. In this grain two consequences of the overlapping of the periods of crystallization may be noted for future reference: at several points the plagioclase has the appearance of growing into the pyroxene in a manner that would be interpreted by some petrologists as proving replacement; but near by exactly the opposite relationship is observable. Further, wedges, tongues, and thin veins of bronzite penetrate short distances along inter-plagioclase boundaries, again in a manner that, at first sight, suggests replacement; but, as is shown below, this also is a result of overlap of the periods of crystallization of the two minerals.

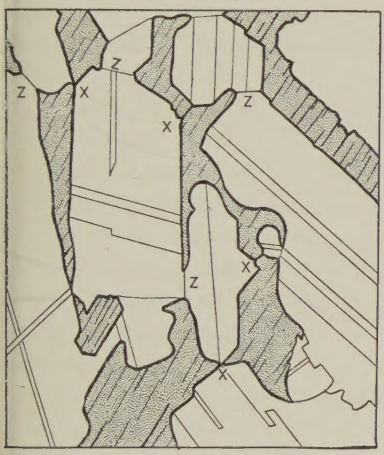
2. *The ophitic relationship between pyroxene and plagioclase.*

A texture approximating to the normal ophitic is seen in some of the mottled anorthosites of A. L. Hall. In these rocks the pyroxenes are virtually restricted to ill-defined dark clots irregularly scattered through the whitish anorthosite. Each clot consists of plagioclase in large excess over bronzite, or clinopyroxene, or both, associated in a manner

reminiscent of the ophitic texture, but differing from it in detail. The bronzite-plagioclase association illustrated in fig. 3 is typical. The fact that the plagioclases, of tabular habit, flattened parallel to (010), are in part welded to one another along straight-line contacts, but in part separated by narrow tongues or wedges of pyroxene, is highly significant. Again there is a strong suggestion of replacement of plagioclase by pyroxene: it *looks* at first sight as if the latter had been able to work its way along the inter-crystal boundaries, and to encroach upon the plagioclases. There is little doubt that, were other minerals involved instead of pyroxene and plagioclase in a normal igneous rock, the texture would be interpreted as indicating replacement. But again there is abundant evidence, in the details of the structure, that the appearance of replacement results from overlap of the periods of crystallization of the two minerals concerned. Because the plagioclase was in large excess over the pyroxene, it began to crystallize first, and gained a long lead. At a relatively late stage the clot consisted of a mush of plagioclase crystals, with entrapped residual liquid, consisting chiefly of potential bronzite with a small felspathic residuum. This material was squeezed between the growing plagioclases, probably by the pressure of crystallization. At numberless points within the clots, and particularly on their outer margins, the evidence for the mobility of the residuum is conclusive: it can often be seen to have executed 'pincer-movements' round plagioclases. Where the encirclement was complete, the two 'veins', moving in from opposite directions, meet at a clearly defined point in the plane of the section, such as the points marked X in fig. 3. Where the encirclement was incomplete, due to exhaustion of material, or to freezing-in of the pyroxene, the two veins do not meet, but the gap was closed by plagioclase drawn from the small amount of still fluid residuum. Thus the two plagioclases were ultimately welded along a (usually) straight-line contact-surface, as at Z in fig. 3. It follows, of course, that many of the contact-surfaces between the two minerals are plagioclase crystal-faces, others are curved. Their significance has already been considered. Less commonly the pyroxene was able to exercise control, and the common boundary runs parallel to a plane of structural significance in the bronzite. This is usually the cleavage direction, as seen at a number of points in fig. 3.

Comparison with a really well-developed ophitic texture shows that in the present case the plagioclases are definitely less well-shaped. The perfect euhedrism of the felspars in the ideal ophitic texture suggests that there was no appreciable overlap of the periods of crystallization.

Thus the plagioclase in the ideal case is 'pre-pyroxene'; but in the texture under consideration the bronzite crystallized simultaneously with the latter part, so to speak, of the plagioclase. In such a simple, two-mineral association, the control would appear to be relative amounts of the two minerals.



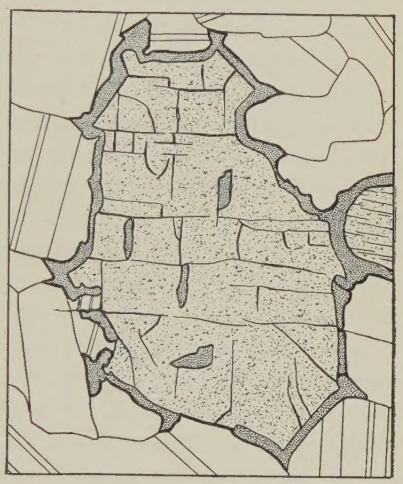


Fig. 3. Fig. 4.

Fig. 3. Sub-ophitic clot in leuconorite. (For discussion see text.) Height of section, 2 mm.

Fig. 4. Isolated bronzite in mottled anorthosite with thin reaction rim of clinopyroxene. Pyroxene and plagioclase contemporaneous; clinopyroxene late-stage or subsequent. Pyroxene grain 2 mm. tall.

3. *Single bronzites with narrow rims of clinopyroxene.*

In the leuconorites and mottled anorthosites some of the isolated bronzites are mantled by a thin rim of brilliantly polarizing clinopyroxene. Such a rim may envelop the whole grain, or it may veneer part only—one end, one side, or one or two corners. It will be seen from fig. 4 that, as was the case with the similar unrimmed bronzites, the pyroxene wedges into the plagioclase mosaic, invariably *between* the component grains; and that the present boundary of the bronzite faithfully follows the outer (clinopyroxene) boundary into all these salients. In view of the evidence given above, it is clear that pyroxene and plagioclase were crystallizing at the same time, and that the fields of development of these two minerals were fully established *before* the clinopyroxene started to form. The latter occupies narrow, sinuous,

parallel-sided zones between the two minerals that, between them, were able to supply all the elements necessary for the formation of the clinopyroxene. There can be no doubt that the prior crystallization of bronzite was essential to the development of the clinopyroxene rims: in these particular rocks no clinopyroxene occurs independently of bronzite.

In seeking an explanation of the clinopyroxene rims, the several analogous structures usually attributed to ionic transfusion naturally come to mind; but there are at least three processes which may have been involved. Firstly, as bronzite and clinopyroxene are successive members of Bowen's discontinuous reaction series, it is natural that, in certain circumstances, earlier formed bronzites should be wrapped round and partially replaced by later clinopyroxene. But this is a consequence of reaction between a solid phase and a liquid, which are no longer in equilibrium on account of falling temperature. This process cannot apply to the case in point, for the two minerals concerned were sensibly solid—though only just, and still at a high temperature—*before* the clinopyroxene was formed. Secondly, ionic transfusion across the pyroxene-plagioclase boundaries, actuated by rise of temperature, and aided possibly by pore-liquids working along the inter-crystal boundaries, might be expected to give precisely the observed relationships. Indeed the conditions could scarcely be more favourable, as both minerals were at the temperature of crystallization, and their crystal lattices therefore in the right condition for ionic interchange in the atomically disordered surface-contact zone. Further, it would not be necessary to introduce ions from some unknown extraneous source, as all the required materials were at hand. Ionic transfusion of this kind would account for the approximate uniformity in width and the other observed features of the rims; but their apparently haphazard development remains a problem. In most recorded instances of this kind, metamorphism is invoked to provide the necessary impetus to bring about the atomic interchange. In this connexion it must be remembered that the particular rock showing the features under discussion is but one member of an enormous complex; and although there is no evidence of general metamorphism, re-heating of an earlier member by later ones is almost inevitable. Such re-heating, possibly to the temperature at which bronzite reacted with plagioclase to form clinopyroxene, would account for the textural relationships here described; but the fact that bronzites with well-developed rims have, as their nearest neighbours, other crystals, either rimless or with imperfect rims, would remain anomalous. The haphazard development of the

clinopyroxene cannot be accounted for by different degrees of reactivity due to varying crystallographic orientation of the two reacting minerals in this instance; but it may well be due to localization of pore-liquids which were activated by rise of temperature.

But, although ionic transfusion on these lines is the most likely means of forming the reaction rims, the writer ventures to suggest an alternative, operating during crystallization. It may well be that, as crystallization proceeded under conditions of maximum atomic mobility, the unwanted ions were expelled from the 'spheres of influence' already ear-marked as potential plagioclase and pyroxene respectively. When the remaining liquid was much reduced in amount, however, viscosity would increase and two-way ionic diffusion across the invisible boundary in the liquid still cushioning the adjacent crystals could become increasingly difficult, and after a time, might be inhibited altogether. Thus within a narrow contact zone the Ca″, Al‴ ions trying to move across into the felspar, and the Mg″, Fe″ ions moving in the opposite direction would be trapped, and at the temperature appropriate to the inversion of bronzite into clinopyroxene, the latter would form. This would be a late-stage phenomenon, and in no sense metamorphic. The impersistence of some rims, and their absence in other cases, then presents no difficulty. Any factor that would delay the final crystallization would allow a clean-cut separation of the pyroxenic and plagioclasic constituents: there would be no laggards among the ions, and therefore no reaction rim.

4. *The coronophitic clots.*

The most interesting texture in this suite of rocks is encountered in the mottled anorthosite that contains the bronzites with reaction rims, described above. In thin section the anorthosite, apart from the clots, consists of large squarish bytownites embedded in a matrix of much smaller plagioclase grains. Apart from the clots there are no accessories. Further, the smaller grains show no evidence of cataclastic structure: they crystallized successively from a melt (fig. 7, right-hand side).

The clots contain bronzite (the most abundant mineral) associated with clinopyroxene in reaction relationship, and a small amount of plagioclase. As the clinopyroxene is vaguely ophitic towards the latter, and is related to the bronzites in a manner recalling corona structure, the texture may be called *coronophitic*.

The characters of a typical coronophitic clot are illustrated in fig. 5. It will be noted that within the clot, the poikilitic clinopyroxenes are of extraordinarily diffuse form, and, by comparison with the bronzites and

even the largest of the plagioclases, are very large. Embedded poikilitically in these clinopyroxenes are bronzites, occasionally in contact, but usually separated from one another by a more or less regular rim of clinopyroxene, and sometimes with intervening irregular tongues of plagioclase in addition. Thus the minerals are the same three as occur

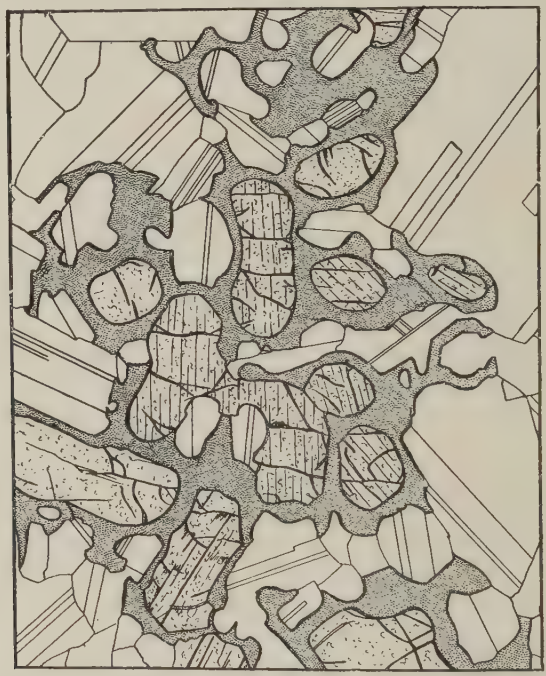
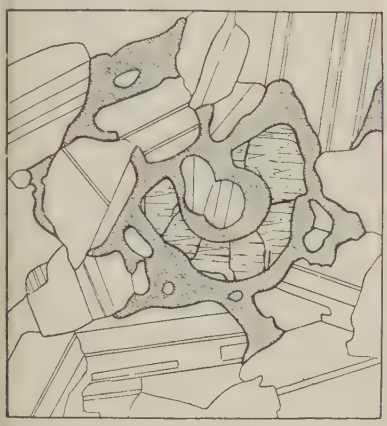


Fig. 5. Coronophitic clot in mottled anorthosite: sub-cylindrical bronzites with overgrowth of clinopyroxene (close stipple), and bytownite. Height of section, 4 mm.

elsewhere in these rocks; but the inter-relationships are strikingly different. The clinopyroxene is much more abundant relative to the bronzite; and while the anorthosite contains rather more bronzites with thin reaction rims than without them, within the clots *all* the bronzites are heavily invested with augitic material. They are also significantly different in shape, as shown by comparison of fig. 2 with figs. 5 and 6. It is clear that the clinopyroxene bears a reaction relationship to the other two minerals in both environments.

The relationship of the augitic material to the bronzites and plagioclases is reminiscent in other rocks of parallel-sided 'channels' winding

between the original crystal grains, and containing a new phase, derived at least in part from one or other of the bordering minerals. Usually such 'channels' are regarded as being of metamorphic origin, the energy needed for the reaction being supplied by a general rise of temperature. Such are the corona structures, described and accounted for on these



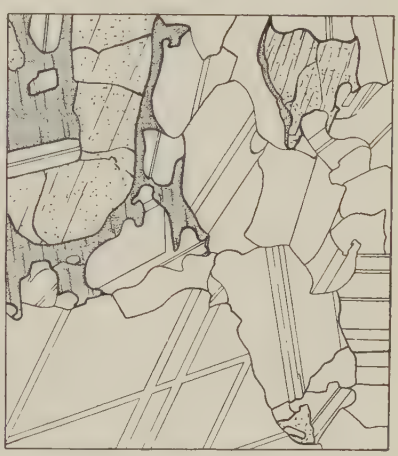


Fig. 6. Fig. 7.

Fig. 6. Bronzite-clinopyroxene-bytownite association in mottled anorthosite, showing particularly the nature of the 'tongues' contemporaneous with surrounding plagioclase. Width of section, 3·5 mm.

Fig. 7. Part of coronophitic clot showing small grains of plagioclase enmeshed in tongue-like protuberances from the clinopyroxene reaction rims.

lines by Shand,[1] who thought that a later intrusion supplied the necessary heat. Recently, Doris Reynolds has described 'channels' of orthoclase penetrating between grains of oligoclase and quartz in a Caledonian granodiorite, metamorphosed in Tertiary times.[2] Her description of the textural relationships between these three minerals would apply almost word for word to the bytownite-bronzite-clinopyroxene association here described, though there are important differences. The genuine corona structures are typically two-ply, and often involve minerals of fibrous habit containing hydroxyl and other fluxes. In the present instance the rim is never two-ply, though two minerals, anhydrous clinopyroxene and

[1] S. J. Shand, On coronas and coronites. Bull. Geol. Soc. Amer., 1945, vol. 56, p. 247.

[2] D. L. Reynolds, The transformation of Caledonian granodiorite to Tertiary granophyre on Slieve Gullion, Co. Armagh, N. Ireland. Internat. Geol. Congr., 18th Session, Great Britain, 1948, Report, 1950, pt. 3, p. 20.

plagioclase, are involved. In the Slieve Gullion case, the orthoclase filling the channels was demonstrably formed from, and replaces the marginal zones of, the oligoclase, for the optical orientation of the former changes at each oligoclase boundary. In the present instance, although there can be no doubt that the bronzites contributed largely to the formation of the clinopyroxene, and although the former are of haphazard orientation, there is no crystallographic relationship between the two pyroxenes: the whole of the clinopyroxene within any one clot is crystallographically continuous. One must infer, therefore, that the clinopyroxene together with the small grains of plagioclase intimately involved with it were precipitated from a liquid phase. The outer bronzites within the clots are uniformly encased in clinopyroxene, a fact that is meaningless if it does not imply essentially the same mode of origin as for the thinner imperfect rims described above. It seems impossible to escape the conclusion that the augitic material, formed by reaction, was fluxed and thus acquired, as it were, crystallographic independence.

Critical evidence bearing on the physical condition of the pyroxenic material is afforded by the many blunt wedges and finger-like processes which penetrate radially for short distances into the plagioclase-mosaic surrounding the clots (figs. 6 and 7). They were invariably inserted *along* inter-crystal boundaries; the pyroxenic material moved *between* crystals, not into them. It looks at first sight as if it had been able to thrust its way between the plagioclases, making room for itself by pushing them aside; but this possibility must be ruled out as impracticable. We must next consider the possibility of the protrusions having been formed by *replacement*, rather than displacement.

It is more difficult to assess the evidence for and against replacement of the plagioclase. If Mg″ and Fe″ ions were available in the reaction zones, they might, under favourable circumstances, work their way along the inter-crystal boundaries, through the contact zones of atomic disorder, producing a narrow channel of clinopyroxene at the expense of the plagioclase. This process would explain why the channels on the outside of a clot penetrate between plagioclases, as well as along bronzite-plagioclase contacts. Nevertheless, although superficial examination suggests a replacive origin, appearances in this case are deceptive. The main argument against replacement is the fact that precisely similar textural relationships are encountered repeatedly in the simpler bronzite-plagioclase association in the sub-ophitic clots, and even where isolated bronzites are embedded in plagioclase. If the clinopyroxene tongues protruding from the reaction rims within the coronophitic clots, and

illustrated in figs. 5 and 6, are replacive, then so are the similar tongues of pyroxene illustrated in figs. 2 and 3; but as we have already seen, the textural relationships in the last two cases are consistent with simultaneous crystallization rather than replacement.

Two points of detail are significant here. Many of the short tongues expand distally and cease abruptly against a plagioclase crystal-face (fig. 6). This is inconsistent with replacement, for there is no reason why replacement should be most extensive at the end of a vein, and no apparent reason why, if the clinopyroxene substance could replace plagioclase on either side, it should not be equally effective in attacking the felspar lying athwart its passage. On the other hand, a picture of a still plastic, largely augitic residuum, propelled by the pressure of the adjacent growing plagioclases and piling up behind an earlier-formed felspar, does not unduly strain the imagination. This relationship is shown repeatedly in figs. 5 and 6. The present pyroxene-plagioclase boundaries at the outer margins of the clots are not the original ones, for the *substance* of the plagioclase as well as of the bronzite was required for the formation of the clinopyroxene, though it is uncertain whether a plagioclasic residuum rather than the solid crystals made the necessary contributions. However, it is obvious from the structural details of the clots that the final residuum contained material from which both clinopyroxene and plagioclase were ultimately precipitated, for small granules of the latter lie between the projecting tongues of the former. It is clear that both minerals crystallized simultaneously (figs. 6 and 7).

Now the heterogeneity of the mottled anorthosite is apparent from the hand-specimen. In effect the dark clots considered alone could appropriately be termed 'augite-melanorite': while the rest of the rock is bronzite-bearing anorthosite. According to the current view, anorthosite represents a natural concentration of plagioclase crystals, formed from basic magma (in this case noritic), out of which the heavy silicates have been separated by gravity, and from which the late magmatic residua have been expelled by filter-press action. The dark clots, therefore, might represent either cognate xenoliths of melanorite, or pockets of residua trapped in the plagioclase crystal mush.

In support of the former hypothesis one may quote the very different mineral composition within and outside the clots, and the striking difference in shape of the bronzites in the two environments. The well-rounded, sub-cylindrical bronzites within the clots stand in striking contrast with the highly irregular isolated grains in the body of the rock. This implies differences in cooling history.

As regards the second hypothesis, it seems to the writer that a weakness lies in the composition of the clots: they are mafic, whereas late-fractions ought surely to be leucocratic. The material limitations of the present study make it impossible to dogmatize on the origin of the coronophitic clots; but crystallization within the clots appears to have proceeded under a different control from that operating in the body of the anorthosite, and therefore the writer favours a xenolithic origin. The effects of re-heating to magmatic temperatures appear self-evident. The general picture involves early-formed bronzites forming small groups, and partly in contact with one another. These were later laid under contribution, together with the adjoining plagioclases, to form a fluid reaction product containing the substance of clinopyroxene in excess of potential bytownite. Clinopyroxene was precipitated first, upon the now rounded bronzite nuclei, but was crystallographically independent of them except at the point where crystallization commenced. The clinopyroxene was quickly joined by plagioclase and the two crystallized simultaneously within the framework imposed by the external felspar mosaic.

Acknowledgements.—The writer is grateful for valuable assistance in this work from Dr. Olive Bradley, Dr. M. K. Wells, and Messrs. A. C. Bishop and R. J. Wyatt; also to Messrs. E. O. Rowland and T. W. Lewis, who made the thin sections and prepared the lantern slides exhibited during the reading of the paper.

Trachy-ophitic texture in Carboniferous basalts.

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[Taken as read June 12, 1952.]

MANY Jedburgh-type olivine-basalts of Carboniferous age in Scotland are characterized by a sub-ophitic texture in their groundmass and a flow structure of their lathy felspar phenocrysts. These characteristics have been frequently reported in the writings of Geikie, Flett, Bailey, Tyrrell, MacGregor, and others and are recognized as important textural features. In the main, however, they have been described as independent features and have been regarded as unrelated phenomena. Tyrrell (1909) alone has remarked on parallel felspars enclosed in plates of augite, and since his description appeared at an early date and has been available to subsequent workers, the lack of further examples indicates either that his discovery has been overlooked or that the texture is very rare.

During an examination of the igneous rocks of the Langholm district, Dumfriesshire, a Jedburgh-type basalt was found possessing a combined flow and ophitic texture. It was originally described by Lady McRobert[1] as the Dinwoodie basalt which occurs as a sheet, roughly half a mile in diameter, capping Greena Hill, four miles south of Newcastleton in Liddesdale. A small quarry cut into the base of the sheet shows a fine, grey non-porphyritic rock with pronounced platy jointing and a lack of vesicles. At higher horizons the rock becomes coarser and decidedly doleritic; its colour turns dark-grey and it contains many slender felspar microphenocrysts with parallel orientation. From the presence of the fine-grained lower margin, the absence of vesicles, agglomeratic material, and iddingsite pseudomorphs after olivine, it is inferred that the sheet is not a lava-flow but a sill which has been intruded at the top of the Fell sandstone.

In thin section, the rock is a typical Jedburgh-type basalt composed of microphenocrysts of thin plagioclase crystals and altered olivines, in a matrix of felspar laths, augite, chlorite, calcite, and iron ores. The relative proportion of these constituents is shown by the mode from which it can be seen that the rock is not completely fresh (table I).

[1] R. W. McRobert, Igneous rocks of Teviot and Liddesdale. Trans. Edinburgh Geol. Soc., 1920, vol. 11, pp. 86–103. [M.A. 1–92.]

Of the phenocrysts, plagioclase is the more abundant and has a composition of $Ab_{40}An_{60}$, length: breadth ratio of 5:1, and an average length of 2 mm. In spite of their length, they are quite different in habit from the felspars of the macroporphyritic Markle-type basalt. The olivine pseudomorphs consist of patches of calcite and dense chlorite which can only be identified with certainty when they exhibit the typical shape of

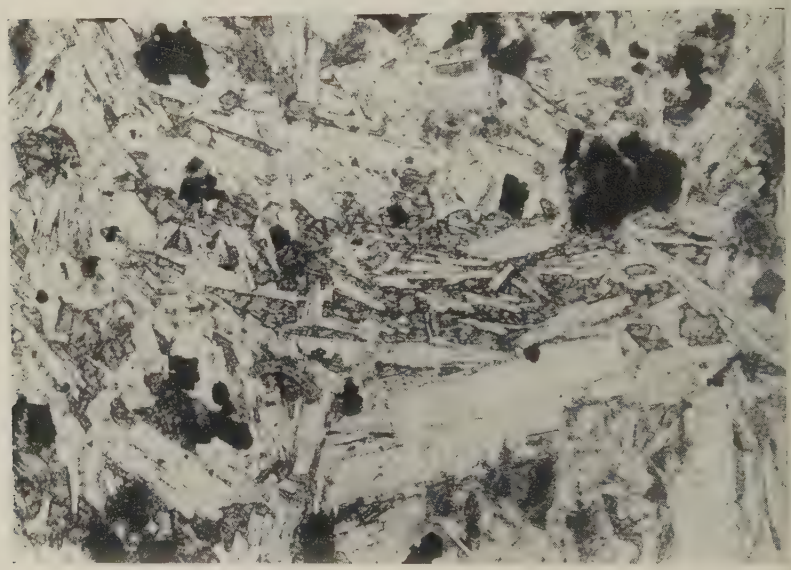

Fig. 1. Trachy-ophitic texture in basalt, Dinwoodie, Dumfriesshire. ×24.

the replaced mineral. As a rule the patches are small and rarely exceed 0·4 mm. in diameter.

The groundmass is composed of small, flow-alined laths of labradorite, of an average length of 0·2 mm., in part intergrown with plates of purplish augite and in part with interstitial fibrous chlorite, calcite, alkali-felspar, and iron ores.

The optical data of the ingredients of the intergrowth is as follows: the plagioclase, as measured on the universal stage, shows complex twinning with (010) as the composition plane and gives an extinction angle of 31° perpendicular to (001), corresponding to a composition of $Ab_{42}An_{58}$. The augite has 2V 53°, α 1·692, and γ 1·716 ± 0·001, indicating a composition $Fe_{20}Ca_{44}Mg_{36}$.

The interstitial felspar is not easy to determine qualitatively and

almost impossible to measure quantitatively. It shows a shadowy complex twinning and has a refractive index below that of Canada balsam, from which data it is probably albite-oligoclase, while from a consideration of the chemical analysis it is likely that it also contains an appreciable quantity of potash (table I).

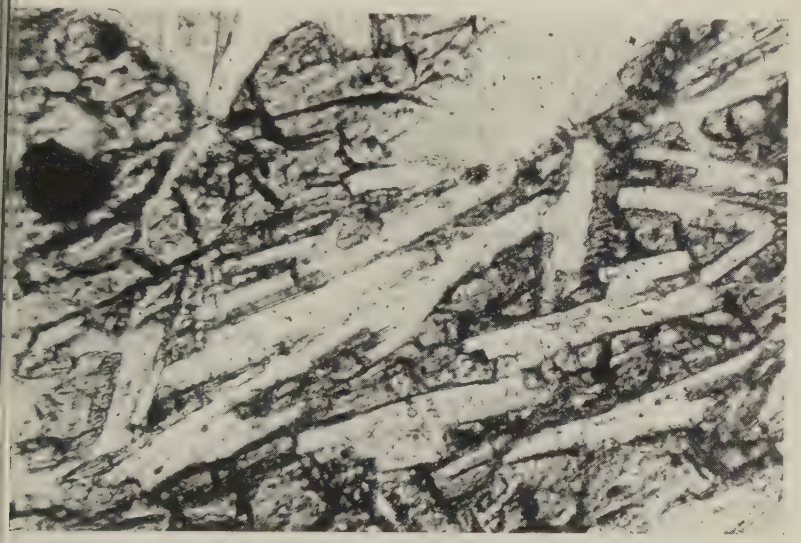

Fig. 2. Enlargement of portion of fig. 1. × 120.

Table I. Chemical analysis (of fine margin) and mode of the Dinwoodie basalt.

SiO_2	45·64	Na_2O	3·62	Felspar	55 %
TiO_2	2·48	K_2O	2·04	Olivine	6
Al_2O_3	18·15	$H_2O+105°$ C.	2·42	Augite	11
Fe_2O_3	4·67	$H_2O-105°$ C.	0·50	Chlorite	17
FeO	6·15	CO_2	2·68	Magnetite	9
MnO	0·19	P_2O_5	0·67	Calcite	2
MgO	2·82				
CaO	7·78		99·81		

The intergrowth between the labradorite laths and the purplish augite differs from the normal ophitic type, in which there is random or even divergent orientation of the felspars, by having the felspar laths in parallel orientation (figs. 1 and 2). These laths are mostly bounded by crystal faces and have irregular margins only when they are in close contact with other felspars. The enclosing augite plates are usually slightly elongated and have an average length of 0·4 mm. with a maximum of

1·7 mm. The plates have very irregular margins due to the many protruding felspars and in some examples they are so full of felspars that a single crystal appears as several apparently discrete triangular patches. Neglecting the flow-structure, this rock texture is clearly of 'sub-ophitic' rather than 'ophitic' character.

Interpretation of the structure.—Since the felspar laths are mostly euhedral and only show irregular margins when they are in close contact with one another it is evident that some growth took place after orientation and whilst the surrounding medium was still entirely fluid. The fact that the augite envelops these euhedral and orientated felspar crystals indicates that it formed after the formation of the felspar laths and after the production of their flow-structure. The sequence of events revealed by the texture is as follows: firstly the formation of the felspar laths, secondly the production of the flow-structure, and thirdly the crystallization of the augite.

Unlike the normal ophitic texture, which has been taken as evidence of simultaneous crystallization of felspar and augite,[1] this variety of the texture provides clear evidence that augite crystallized later than the felspar laths. The texture is not confined to the Carboniferous basalts, for, in addition to being recorded by Tyrrell,[2] it has been described by Krokström[3] in the Tertiary olivine-basalts of Greenland. In view of its distribution, its distinctive nature, and its petrogenetic significance, it seems that a precise term is required to distinguish it from ophitic, about which views conflict. I therefore suggest *trachy-ophitic*, as almost self-explanatory and introducing no new or unfamiliar adjectives.

[1] R. A. Daly and T. F. W. Barth, Dolerites associated with the Karroo system, South Africa. Geol. Mag., 1930, vol. 67, pp. 97–110.

[2] G. W. Tyrrell, The petrology of the Auchineden district, Kilpatrick Hills. Trans. Geol. Soc. Glasgow, 1909, vol. 13, pp. 337–343.

[3] T. Krokström, On the ophitic texture and order of crystallization in basaltic magma. Bull. Geol. Inst. Univ. Upsala, 1932, vol. 24, pp. 197–216.

Hydrous micas.

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[Read March 27, 1952.]

HYDROUS micas differ from normal micas in that they contain less potassium and more water. In the calculation of structural formulae from their chemical analyses, two methods have been used which rely on the following different assumptions:

1. As these minerals are often fine-grained and may contain adsorbed water, no reliance is placed on the value of H_2O+ (water lost above 105° C.) as a measure of structural water. The water content is ignored and the structural formula is calculated on the basis of 20 oxygens plus 4 hydroxyls per structural unit.[2] This method has been used by Hendricks and Ross[3] and by Grim and Bradley.[4]

2. The water which is recorded as H_2O+ in the chemical analysis is assumed to represent hydroxyl groups in the aluminosilicate layers of the minerals. Thus, instead of having 20 oxygens and 4 hydroxyl ions per structural unit as in normal micas, formulae are derived which show less than 20 oxygens and more than 4 hydroxyls, the total oxygen plus hydroxyl remaining 24. This method has been used by Brammall, Leech, and Bannister.[5]

The above treatments generally result in structural formulae which depart considerably from those of ideal micas. In particular, the interlayer positions are little more than half-filled and the number of ions in octahedral co-ordination, in the dioctahedral type of mica, is somewhat removed from 4.

Recently N. V. Shishkin[6] has established the existence of oxonium

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[2] We take as the structural unit a cell of volume $abc \sin\beta/m$, where a, b, c, and β are the unit-cell parameters, and m is the number of layers per unit cell. This structural unit is chosen as it is independent of polymorphism of micas (S. B. Hendricks and M. E. Jefferson, Amer. Min., 1939, vol. 24, p. 729 [M.A. **7**–496]).

[3] S. B. Hendricks and C. S. Ross, Amer. Min., 1941, vol. 26, p. 683. [M.A. **8**–275.]

[4] R. E. Grim and W. F. Bradley, Chapter V *in* X-ray identification and crystal structures of clay minerals. Min. Soc., London, 1951. [M.A. **11**–253.]

[5] A. Brammall, J. G. C. Leech, and F. A. Bannister, Min. Mag., 1937, vol. 24, p. 507.

[6] N. V. Shishkin, Zhurn. Obshcheĭ Khim. (Acad. Sci. U.S.S.R.), 1951, vol. 21, p. 456.

ions $(H_3O)^+$ in the system H_2O–SO_3–Fe_2O_3–$(NH_4)_2O$. He believes that

$$[Fe_3(OH)_6(SO_4)_2]^-H_3O^+, \qquad [Fe_3(OH)_6(SO_4)_2]^-NH_4^+,$$

and

$$[Fe_3(OH)_6(SO_4)_2]^-K^+$$

are isostructural, the potassium, ammonium, and oxonium ions replacing one another isomorphously.

In view of the above evidence for the replacement of potassium ions by oxonium ions and as these ions are approximately the same size, it seems probable that the high water and low potassium content of hydrous mica is due to the replacement of potassium by oxonium ions. To test this hypothesis we have calculated the structural formulae of some hydrous micas. The analyses used are those given by Brammall, Leech, and Bannister (loc. cit.) for hydromuscovites A and B, and those of Grim, Bray, and Bradley[1] for illites 1 and 2. These analyses were selected because the minerals were well characterized and pure. We have confined our attention to dioctahedral micas as hydrobiotites are usually vermiculitic.[2]

TABLE I. Chemical analysis of illite with calculation of structural formula.

		Atomic proportions				Atoms per structural unit.	
		Oxygen.	Cations.				
SiO_2	51·22	1·7056	0·8528	Si	6·7495	8·0000	
Al_2O_3	25·91	0·7626	0·5084	Al	1·2505		
					2·7732		
TiO_2	0·53	0·0132	0·0066	Ti	0·0522	4·02	
Fe_2O_3	4·59	0·0861	0·0574	Fe^{3+}	0·4543		
FeO	1·70	0·0237	0·0237	Fe^{2+}	0·1876		
MgO	2·84	0·0704	0·0704	Mg	0·5572		
CaO	0·16	0·0029	0·0029	Ca	0·0230	1·85	
Na_2O	0·17	0·0027	0·0054	Na	0·0427		
K_2O	6·09	0·0646	0·1292	K	1·0226		
H_2O+	7·14	0·3692	0·7924	H	2·2714 = 0·7572(H_3O^+)		
					4·0000 = 4·0000(OH)	4(OH)	
ΣO	—	3·1280	—	O	24·7566 − (H_3O + OH) = 20	20(O)	

Table I shows the calculation of the structural formula of illite 2 assuming that the excess water is present as oxonium ions occupying interlayer positions. Columns 1, 2, and 3 are self-explanatory. To obtain the number of ions per structural unit, shown in column 4, column 3 must be multiplied by a factor n. To determine n we make the following assumptions.

(*a*) There are 20 oxygens and 4 hydroxyl ions per structural unit, i.e. that the oxygen-hydroxyl framework is identical with that of a normal mica.

[1] R. E. Grim, R. H. Bray, and W. F. Bradley, Amer. Min., 1937, vol. 22, p. 813. [M.A. **7**–12.]

[2] J. W. Gruner, Amer. Min., 1934, vol. 19, p. 557. [M.A. **6**–181.]

(*b*) The excess water over that required for 4 hydroxyl ions is present as interlayer oxonium ions, ny per structural unit. We then have the following equations:

$$4/n+3y = \text{(atomic proportion of hydrogen)},$$

and $$24+ny = \text{(atomic proportion of oxygen)},$$

and a solution of these gives n.

Column 5 gives the number of ions occupying the various positions in the structure. The number in tetrahedral co-ordination is made equal to 8 per structural unit by putting all the silicon and the necessary amount of aluminium in this position. The remaining aluminium together with the iron, titanium, and magnesium is put into positions of octahedral co-ordination, while the large ions, calcium, sodium, potassium, and oxonium are given interlayer positions.

TABLE II. Atomic cell contents of hydromuscovite and illite.

	Hydro-muscovite A.		Hydro-muscovite B.		Illite 1.		Illite 2.	
Si ...	6·1183	8·00	6·3629	8·00	6·6325	8·00	6·7495	8·00
Al ...	5·6467	—	5·3670	—	3·9181	—	4·0237	—
Ti ...	—	—	—	—	0·0501	—	0·0522	—
Fe^{3+} ...	0·0712	3·97	0·1122	3·96	0·5105	4·04	0·4543	4·02
Fe^{2+} ...	0·0396	—	0·0300	—	0·1685	—	0·1876	—
Mg ...	0·0981	—	0·0861	—	0·7752	—	0·5572	—
Ca ...	0·0309	—	0·0364	—	0·0636	—	0·0230	—
Na ...	0·1171	1·99	0·0553	1·84	0·0127	2·02	0·0427	1·85
K ...	1·3547	—	1·3110	—	1·1704	—	1·0226	—
H ...	5·5423	4 OH	5·3197	4 OH	6·3351	4 OH	6·2714	4 OH
O ...	24·5159	20 O	24·4400	20 O	24·7744	20 O	24·7566	20 O

This method has been applied to the four hydrous micas and Table II shows the complete structural formulae obtained. It will be seen that the formulae derived by these calculations show good agreement with those of normal dioctahedral micas in having the total of interlayer cations close to 2 and octahedral cations to 4 per structural unit. An ideal general formula for hydrous micas would be

$$(Ca,Na,K,H_3O)_2(Al,Ti,Mg,Fe)_4(Si,Al)_8O_{20}(OH)_4.$$

Table III shows a comparison of the structural formulae obtained by calculation from the various sets of assumptions noted above. It will be seen that better agreement with the ideal mica formula is obtained by using our assumptions than by either of the others.

In addition to the above we have considered other analyses of hydrous micas, including glauconites, given in the literature. Generally the formulae obtained are in better agreement with that of an ideal mica

than those derived by other methods of calculation. However, no definite conclusion can be drawn from studying these structural formulae in detail as in most cases the purity of the samples was not satisfactorily established.

TABLE III. Comparison of interpretations of structural formulae.

	Method of calculation.	Tetrahedral ions.	Octahedral ions.	Interlayer ions.
Ideal mica	—	8·00	4·00	2·00
Hydromuscovite A ...	a	8·00	3·97	1·99
	b	8·00	3·76	1·44
	c	8·00	3·03	1·38
Hydromuscovite B ...	a	8·00	3·96	1·84
	b	8·00	3·77	1·34
	c	8·00	2·98	1·29
Illite 1	a	8·00	4·04	2·02
	b	8·00	3·68	1·21
	c	8·00	3·94	1·27
Illite 2	a	8·00	4·02	1·85
	b	8·00	3·64	1·06
	c	8·00	4·26	1·11

Methods of calculation:

a. Calculated assuming presence of H_3O^+ ions in addition to 20 oxygen and 4 hydroxyl ions per structural unit.
b. Calculated assuming that oxygen + hydroxyl = 24 per structural unit.
c. Calculated assuming presence of 20 oxygen and 4 hydroxyl ions per structural unit.

During the preparation of this paper our attention was directed to evidence presented by Ganguly[1] for the existence of oxonium ions as the exchangeable cations in hydrogen-saturated kaolinite, muscovite, and montmorillonite.

Conclusion.—It is our opinion that the excess of water and deficiency of potassium in the hydrous micas compared with the normal micas can be explained by the presence of oxonium ions in the interlayer positions. The consistency of the formulae derived above is adduced to be evidence in support of this hypothesis.

[1] A. K. Ganguly, Soil Sci., 1951, vol. 71, p. 239. [M.A. 11–450.]

The unit cell and space-group of alamosite ($PbSiO_3$).

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[Communicated by Dr. J. W. Jeffery; read June 12, 1952.]

ALAMOSITE was first described by Palache and Merwin,[1] who thought it might be isomorphous with wollastonite. For that reason it has been re-examined, using X-ray methods.

A specimen from the original locality at Alamos, Sonora, Mexico (B.M. 1910,330) was made available through the courtesy of the British Museum (Natural History), and in physical appearance it tallied with the original description. The crystals were aggregates of fibres arranged in bundles which cleaved perfectly perpendicular to the fibre axes. Small tablets could be readily cut out for X-ray analysis. The refractive indices were very high and the dispersion was large. As the axial ratios found by X-ray methods agreed with those given by Palache and Merwin, the latter's chemical analysis and density determination were not repeated.

Unit cell.—From Weissenberg photographs the unit-cell dimensions were found to be:

$$a\ 11{\cdot}28\pm0{\cdot}05,\ b\ 7{\cdot}03\pm0{\cdot}01,\ c\ 13{\cdot}06\pm0{\cdot}05\ \text{Å.},\ \beta\ 120^\circ\pm30'.$$

Using Palache and Merwin's density of $6{\cdot}488\pm0{\cdot}003$ and their chemical analysis, which confirmed the formula as $PbSiO_3$, Z (number of molecules in the unit cell) was found to be 12·3. No alternation of intensities which might indicate pseudo-symmetry was observed.

The $h0l$ reflections were present only when $l = 2n$ and the space-group is therefore Pc or $P2/c$, which differ only in the possession of a centre. Tests for piezo-electricity with a Giebe-Scheibe oscillator gave negative results and, as the X-ray photographs show very many accidental absences, the centred group $P2/c$ is to be preferred.

Experimental technique.—The crystal studied was tabular, the larger faces being (010), and was mounted on goniometer arcs to rotate about [010]. To decrease absorption, Weissenberg photographs, including that of the zero layer, were taken with the beam inclined at less than 70° to the axis of rotation. Weissenberg photographs about [010] do not

[1] C. Palache and H. E. Merwin, Amer. Journ. Sci., 1909, ser. 4, vol. 27, p. 399.

show the $0k0$ reflections, essential for the space-group determination, so the latter were examined separately without resetting the crystal. Knowing the length of the b-axis from the layer-line spacings, the Weissenberg camera was inclined so that each $0k0$ reflection in turn was set exactly at the Bragg angle. The [010] axis was displaced by 1° in an arbitrary direction from the axis of rotation and the crystal was set to revolve continuously. It was thus assured that the crystal would pass twice per revolution through the Bragg angle. Each $0k0$ reflection up to $\theta = 40°$ was in this way recorded separately on a small stationary film, about ten minutes being adequate for each exposure.

Comparison with parawollastonite.—The cell dimensions of monoclinic (para-)wollastonite found by Barnick[1] can be compared with those found for alamosite if the axes a, b, and c used above are changed to new axes a', b', and c' by the transformation $a' = -2a-c$, $b' = -b$, and $c' = c$. In this new orientation dimensions of the two minerals correspond as follows:

Wollastonite.	*Alamosite.*
a 15·36 Å.	a′ 19·96 Å.
b 7·29	b′ 7·03
c 7·08	c′ 13·06
β 95° 24·5′	β 96° 30′
Z = 12	Z = 24
Space-group $P2_1/c$	Space-group in this orientation $B2/a$

Previous goniometric measurements of alamosite.—Palache and Merwin referred their morphological description of alamosite to the above transformed axes. The axial ratios given by the X-ray measurements are: $a/b = 2\times1{\cdot}384$ and $c/b = 2\times0{\cdot}928$, with β 96° 30′, in fair agreement with Palache and Merwin's values of $a/b = 1{\cdot}375$, $c/b = 0{\cdot}924$, β 95° 50′.

Discussion.—The ionic radius of Pb^{++} is 1·32 Å. as against 1·06 Å. for Ca^{++}. If alamosite were isomorphous with monoclinic wollastonite it would be expected that its cell would be somewhat greater in all directions than that of wollastonite; however, an increase is found in one direction only (along the a' cell edge), while the b'-axis shows a decrease, and the c'-axis is somewhat less than twice the length of the corresponding dimension of wollastonite. Alamosite does not show the pseudo-symmetry of wollastonite (halving of the b-axis). It is unlikely, therefore, that alamosite could be used for the analysis of the structure of wollastonite by the method of isomorphous series. Powder photographs are

[1] M. Barnick, Mitt. Kaiser-Wilhelm-Inst. Silikatforschung, 1936, no. 172; Naturwiss., 1935, vol. 23, p. 770. [M.A. 6–332.]

unlike those of wollastonite. It seems, however, quite possible that alamosite may contain Si_3O_9 rings for the following reasons:

i. $\beta = 120°$ and the lattice is thus roughly hexagonal. The cleavage (010) is excellent and could be accounted for by layers of Si_3O_9 rings parallel to (010).

ii. $Z = 12$ and there are 4 atoms in each general position; the independent units of structure would then be 3Pb, 3Si, and 9O—not inconsistent with the presence of Si_3O_9 rings.

iii. One refractive index is widely separated from the other two (α 1·947, β 1·961, γ 1·968) and may indicate anisotropic structure units such as Si_3O_9 rings.

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An unusual cordierite-rock from Upington, Cape Province.

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[Taken as read March 27, 1952.]

Introduction.

SAMPLES of an unusual cordierite-rich rock from near Upington, Cape Province, were collected by Dr. A. Poldervaart who kindly passed them to me for further study. This paper presents the results of the petrographic examination together with chemical analyses of the rock and of cordierite and biotite, which are two of the constituent minerals.

The rock has a most striking appearance. The major constituent is deep-brown cordierite occurring as porphyroblasts measuring up to an inch in size. Occasional flakes of biotite are present, while the interstitial matter appears to consist principally of quartz with some felspar and white mica. The rock has not the typical banded structure of a gneiss nor does it possess the characteristic fabric of a hornfels.

It was first mentioned by E. J. Dunn in 1872 (Rogers and du Toit, 1910). Dunn called the small hill which makes the entire outcrop 'Tourmaline Kop'. The rock was identified by Drs. A. W. Rogers and A. L. du Toit (1910) as a cordierite-bearing rock. Rogers (1910) again refers to it in his article on the Kheis series. He includes two photographs of the hill, one of which is reproduced by Dr. L. C. King in his book 'South African Scenery'. No further data are given by Rogers in this later article, but he suggests that the rock was formed by incorporation of Kheis sediments in a granite magma.

Methods.

Owing to the close similarity between the specific gravity and refractive indices of the cordierite and quartz it was found expedient to cut slices of the rock and pick out the large cordierite crystals by hand so as to eliminate contamination by quartz. Further separation was done by centrifuge and electromagnet. Refractive indices were determined in sodium-light using a cell with temperature control. Optic axial angles were determined on grains showing acute bisectrix figures and direct measurements were made using a 5-circle universal stage.

Petrography.

The cordierite crystals are generally xenoblastic though idioblastic outline can be seen in some instances (fig. 1). Pinakoidal cleavage is prominent. Cyclic twinning occurs fairly commonly. Pleochroic haloes have not been found. The cordierite crystals are remarkably free from inclusions, and although apatite, iron ore, biotite, sericite, and andalusite do occur as inclusions, the last three are rare and the ore is mainly in the form of minute black specks. Alteration, which is not pronounced, is to a brownish-yellow isotropic substance and to a pale-green mica. The only other minerals of nearly comparable size to the cordierites are sporadically distributed crystals of potash-felspar and biotite. The remaining minerals occur interstitially. The felspars are invariably anhedral, the plagioclase is clear and unaltered, and has the composition of oligoclase.

The potash-felspar, which often forms comparatively large irregular crystals, is of a peculiar type with characteristic hazy cross-hatching. The refractive indices are slightly higher than normal; the optic axial angle is large and there is parallel extinction on (001). Apart from the much higher 2V it resembles the soda-microcline described by Professor H. H. Read (1923) as occurring in the Arnage-type rocks. It is apparently unstable in this mineral assemblage and is being replaced mainly by sericite and to a lesser extent by quartz and sillimanite. Biotite and andalusite are also apparently metastable, the former showing alteration to sericite and the latter to sillimanite. Andalusite crystals, except when in contact with quartz, invariably show peripheral armouring by a zone of sillimanite. Apatite and zircon are present as accessory constituents. The latter shows vivid pleochroic haloes in biotite. Blue tourmaline is rare and sporadic in distribution.

Table I. Minerals of the cordierite-rock, Upington.

	Mode.	Grain-sizes in mm. Average.	Grain-sizes in mm. Maximum.	Refractive indices α	Refractive indices β	Refractive indices γ.	$2V_{\alpha}$.
Quartz	12·4	0·17×0·14	2·8×0·6	1·544	—	1·553	—
Potash-felspar	3·2	1·34×0·89	6·2×4·6	1·518	1·525	1·528	80°
Oligoclase	5·8	0·75×0·46	5·0×4·0	on cleavage flakes 1·534–1·537			83–86°
Cordierite	63·1	5·5×3·7	25·0×12·0	·543	1·553	1·555	69–74°
Alteration products of cordierite	4·9	—	—	—	—	—	—
Sericite	4·2	0·24×0·06	2·1×0·5	—	1·592	—	41°
Biotite	1·6	1·55×0·78	15·0×4·0	1·595	—	1·649	0–5°
Sillimanite	3·4	—	1·5×0·3	—	1·671	—	—
Andalusite	1·1	0·46×0·25	1·6×0·5	1·628	1·638	1·639	84°
Iron ore	0·2	0·04×0·03	0·4×0·12	—	—	—	—
Apatite	0·1	0·09×0·06	0·76×0·66	1·634	—	1·638	—
	100·0						

FIG. 1. Cordierite-rock, Upington, showing idioblastic cordierite set in quartz. Ordinary light. × 5.

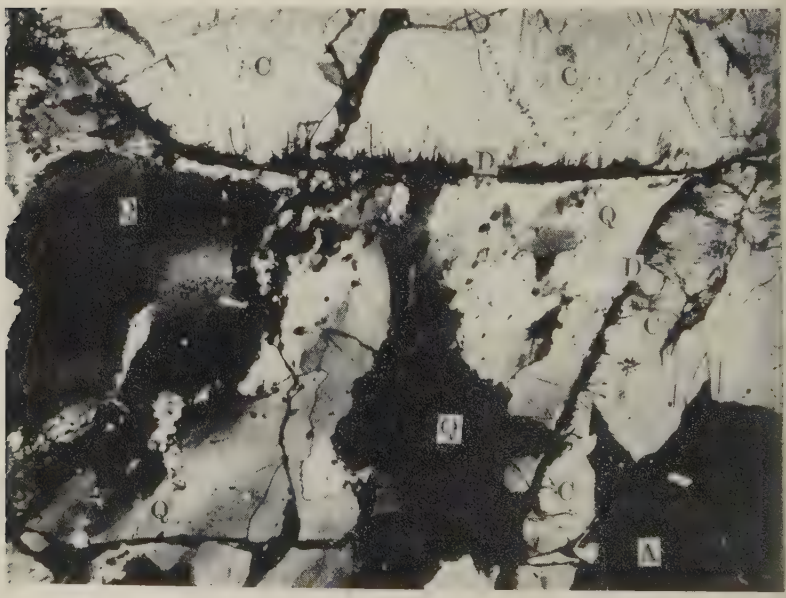

FIG. 2. Cordierite-rock, Upington, showing cordierite (C) bordered and penetrated by isotropic decomposition product (D), optically strained quartz (Q), and andalusite (A). Crossed nicols. × 53.

A peculiarity of structure is that the quartz, micas, felspars, and sillimanite generally show the effects of strain (fig. 2) whereas the cordierite is rarely affected. Table I lists the mode, grain-sizes, and chief optical properties of the minerals.

TABLE IIa. Chemical analysis of cordierite from cordierite-rock, Upington.

Analyst, P. L. le Roux, Division of Chemical Services, Pretoria.

Analysis.		Atomic ratios.		Atomic ratios to 18O.	
SiO_2	48·40	$Si^{\cdots\cdot}$	0·8066	5·042	5·04
TiO_2	0·05	$Al^{\cdots}$	0·6304	3·941	3·94
Al_2O_3	32·15	$Fe^{\cdot\cdot}$	0·1361	0·851	
Fe_2O_3	nil	$Mn^{\cdot\cdot}$	0·0032	0·020	2·00
FeO*	9·80	$Mg^{\cdot\cdot}$	0·1812	1·133	
MnO	0·23	$OH^{\cdot}$	0·1756	1·097	1·10
MgO	7·25	$O^{\cdot\cdot}$	2·8793	18·000	18·00
CaO	trace				
Na_2O	0·39	Formula: $(Mg,Fe^{\cdot\cdot},Mn)_{2\cdot00}Al_{3\cdot94}Si_{5\cdot04}O_{18}.(H_2O)_{1\cdot10}$			
K_2O	0·07				
H_2O+	1·58	$Mg_2Al_4Si_5O_{18} = 56{\cdot}53\ \%$			
H_2O-	0·16	$(Fe,Mn)_2Al_4Si_5O_{18} = 43{\cdot}47\ \%$			
P_2O_5	0·03	Sp. gr. 2·66			
	100·11	α 1·543, β 1·553, γ 1·555, $2V_\alpha$ 71° 40′ (average)			

* The values originally given were FeO 3·74; Fe_2O_3 5·68. Because of the exceptionally high Fe_2O_3 check determinations were made by my colleague Mr. H. C. G. Vincent and the average of five of his results is quoted here.

TABLE IIb. Chemical analysis of biotite from cordierite-rock, Upington.

Analyst, H. C. G. Vincent.

Analysis.		Atomic ratios.		Atomic ratio to 12O.	
SiO_2	34·77	$Si^{\cdots\cdot}$	0·5789	2·6790	4·00
Al_2O_3	19·05	$Al^{\cdots}$	0·3740	1·3210 1·7312 0·4102	
TiO_2	2·84	$Ti^{\cdots\cdot}$	0·0355	0·1645	2·93
Fe_2O_3	0·88	$Fe^{\cdots}$	0·0110	0·0510	
Cr_2O_3	nil	$Fe^{\cdot\cdot}$	0·2883	1·3350	
FeO	20·71	$Mn^{\cdot\cdot}$	0·0014	0·0065	
MnO	0·10	$Mg^{\cdot\cdot}$	0·2076	0·9607	
MgO	8·37	$Ca^{\cdot\cdot}$	0·0046	0·0215	0·89
CaO	0·26	$Na^{\cdot}$	0·0078	0·0358	
BaO	trace	$K^{\cdot}$	0·1802	0·8344	
Li_2O	nil	$OH^{\cdot}$	0·3818	1·7670	1·77
Na_2O	0·24	$O^{\cdot\cdot}$	2·5921	12·0000	12·00
K_2O	8·49				
H_2O+	3·44	Formula: $(K,Na,Ca)_{0\cdot89}(Mg,Fe^{\cdot\cdot},Mn,Al,Ti)_{2\cdot93}$			
H_2O-	0·33	$(Si,Al)_{4\cdot00}O_{12}.(H_2O)_{1\cdot77}$			
Cl	nil				
F	nil	Sp. gr. 3·06			
	99·48	α 1·595 (pale straw), γ 1·649 (reddish brown), $2V_\alpha$ 0–5°			

The analysis of the cordierite shows good correspondence with the standard formula. According to A. N. Winchell's diagrams (1937) a cordierite containing 43·5 % $Fe_2Al_4Si_5O_{18}$ should have α 1·551, β 1·558, γ 1·564, Sp. gr. 2·67, $2V_\alpha$ 48°. R. E. Folinsbee (1941), on the other hand, gives different graphs for correlation of chemical and optical properties in cordierites, and the Upington cordierite shows much closer agreement with these. A comparison between the properties of the Upington cordierite and the values obtained from Folinsbee's graphs for a cordierite of similar composition is given below.

	Upington cordierite.	Folinsbee's data.
γ plotted against composition	1·555	1·560
$\gamma-\alpha$ „ „ „	0·0118	0·0117
2V „ „ weight of effective alkalis ...	71° 40′	68°

In view of the variability in optical properties of cordierite, attention to which has been drawn by A. N. Winchell (1937) and A. Brammall (1933) amongst others, closer agreement is not to be expected.

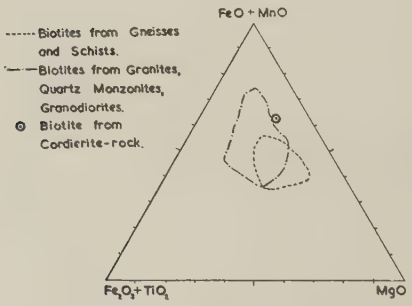

Fig. 3. Plot of the biotite from the cordierite-rock, Upington, on the basis of E. W. Heinrich's diagram (1946).

The biotite analysis shows slight deficiencies in the W, XY, and OH groups. These, however, are in no way abnormal and there is very fair agreement with the general formula $W(X,Y)_{2-3}Z_4O_{10}(O,OH,F)_2$ (Berman, 1937). The absence of fluorine and chlorine is noteworthy. Plotted on a triangular diagram with apices $FeO+MnO$, $Fe_2O_3+TiO_2$, and MgO, according to the method employed by E. W. Heinrich (1946), this biotite falls outside all the fields, but is nearest to the fields for granites, quartz-monzonites, and granodiorites and for gneisses and schists (fig. 3). This result is to be expected considering the peculiar composition of the rock and the fact that biotites from pelitic rocks are not included. The relationship between the index of refraction (γ) and chemical composition (weight percentage $FeO+2(Fe_2O_3+TiO_2)$) shows very good agreement with E. W. Heinrich's curve, the value obtained from the graph being 1·650 and the measured value 1·649. The biotite

lies approximately on the boundary between the fields for biotites associated with muscovite, topaz, &c., and for biotites unaccompanied by other mafic minerals when plotted on the triangular diagram adopted by S. R. Nockolds (1947) with apices MgO, total Fe as FeO, and Al_2O_3. The reddish-brown colour is to be expected from a biotite with high FeO and TiO_2 and low MgO according to A. J. Hall (1941).

TABLE III. Chemical analysis of cordierite-rock, Upington.

Analyst, P. L. le Roux, Division of Chemical Services, Pretoria.

Analysis.		Norm.		Mode.	
SiO_2	52·39	Quartz	30·8	Quartz	12·4
TiO_2	0·25	Orthoclase	8·9	K-felspar	3·2
Al_2O_3	29·29	Albite	8·4	Oligoclase	5·8
Fe_2O_3	3·92	Anorthite	1·1	Cordierite	63·1
FeO	3·59	Corundum	25·6	Alteration products of cordierite	4·9
MnO	0·18	Hypersthene En	13·4	Sericite	4·2
MgO	5·37	Hypersthene Fs	3·4	Biotite	1·6
CaO	0·38	Ilmenite	0·5	Sillimanite	3·4
Na_2O	1·03	Magnetite	5·6	Andalusite	1·1
K_2O	1·47	Apatite	0·3	Iron ore	0·2
H_2O+	2·41	Water	2·6	Apatite	0·1
H_2O-	0·21		100·6		100·0
P_2O_5	0·19				
	100·68				

Composition calculated to ACF diagram of Eskola (Turner, 1948, p. 57). A 59·5, C 0·85, F 39·65.

The high corundum content of the norm is a reflection of the mica and aluminium silicates present in the mode. The rock is manifestly of sedimentary origin having all the characteristics of sedimentary parentage and it lies in the sedimentary field when plotted on a Or. Cor—Ab.—An. Femic triangular diagram (fig. 4). Compared with the average of 78 Palaeozoic shales (Clarke, 1924) it is high in alumina and magnesia and low in silica, lime, and potash. This difference in composition may be due to an initial peculiarity of the sediment, though this is considered unlikely. Alternatively, it may have been acquired later as the result of alumina and magnesia metasomatism.

The texture and mineral assemblage of this rock are both peculiar and difficulties are encountered in trying to classify it. In texture the rock is porphyroblastic but shows no gneissic banding, and the interstitial material is not hornfelsic but shows granulation of the quartz and other features consistent with the operation of stress at a late stage in the metamorphism (fig. 2).

The mineral assemblage fits into neither the pyroxene-hornfels nor the amphibole-hornfels facies of F. J. Turner (1948, pp. 70–76), sericite and potash-felspar being anomalous in the former case and the association potash-felspar–cordierite in the latter. The components suggested

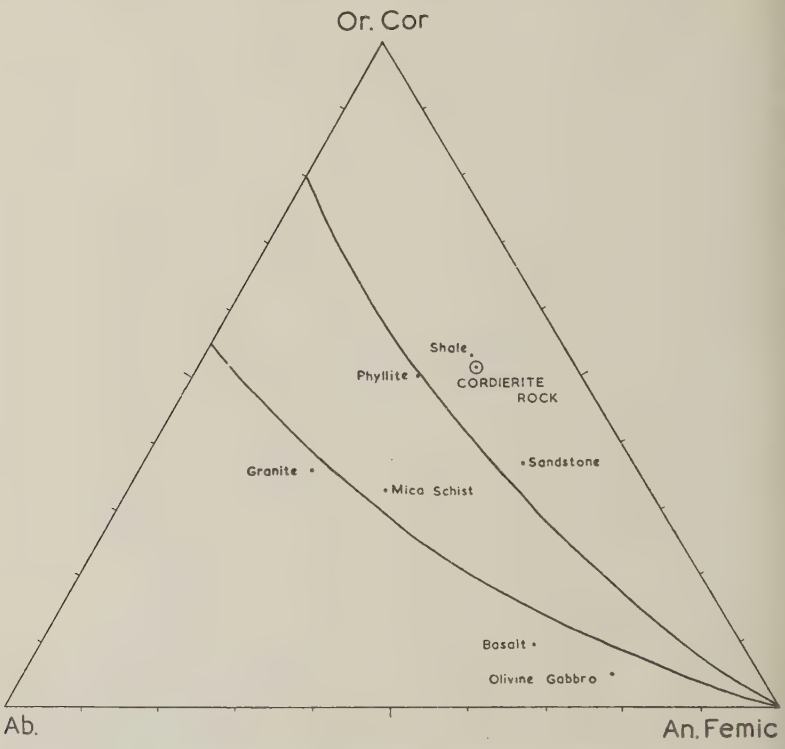

FIG. 4. The average normative composition (excluding quartz) of the commoner rock types. After A. Brammall (1933).

by the mineralogy and chemical composition of the constituents are: SiO_2; Al_2O_3; (Mg,Fe,Mn)O; $(Na_2,Ca)O.Al_2O_3$; $K_2O.Al_2O_3$; and H_2O. Applying the mineralogical phase rule one would expect an equilibrium assemblage of six phases, whereas in fact there are eight phases present. These anomalies all suggest disequilibrium. Judging by the microscope evidence, the unstable minerals in this association appear to be potash-felspar, andalusite, and possibly biotite, all of which are partially replaced by sericite, sillimanite, and quartz. If this is a correct interpretation, the rock formerly consisted essentially of a six-phase assemblage

corresponding to class 2 of Turner's pyroxene-hornfels facies, viz. andalusite-cordierite-plagioclase-quartz-orthoclase-biotite, with sillimanite metastable and partially replacing andalusite. As the temperature dropped and stress became relatively more important, conditions were such as to favour the development of minerals belonging to the cordierite-anthophyllite subfacies of the amphibole facies. Andalusite (or sillimanite), potash-felspar, and water reacted to form sericite and quartz. This reaction, however, was not completed and the resulting assemblage contains minerals of both facies. It is possible that the sillimanite may not have been formed at an early high-temperature stage of the metamorphism and that it has resulted from late metasomatic crystallization similar to that envisaged by J. Watson (1948) in the Kildonan migmatites of Sutherland. Metasomatism has certainly played a part in the reconstruction of the rock if only in producing the sporadic blue tourmalines, the apatite, and the water necessary for sericitization.

Comparison with similar rock types.

The cordierite-bearing Orijärvi rocks from Finland described by P. Eskola (1914, 1915) and the Arnage-type rocks from Aberdeenshire described by H. H. Read (1923) present the closest analogies to the Upington cordierite-rock.

Many types of cordierite-bearing rocks occur in the Orijärvi region. Those that appear most closely comparable to the Upington rock are the andalusite-bearing quartz-mica-rock and the cordierite-gneiss, but in both cases there are significant differences. These Orijärvi rocks are equilibrium assemblages considered to have been developed under conditions of moderate temperature and pressure, with the former dominant and in the presence of excess water. Neither contains potash-felspar which is incompatible with cordierite in this region. The textures of the rocks are also quite different, particularly in the case of the andalusite-bearing quartz-mica-rock which is strongly brecciated and very variable in composition. The calculated chemical composition of the cordierite-gneiss shows higher SiO_2, CaO, and K_2O and lower Al_2O_3, MgO, Na_2O, and H_2O, than the Upington rock. Both these Orijärvi rocks are considered by Eskola to be of metasomatic origin.

The rocks of the Arnage type described by Read differ from the Upington rock in containing abundant 'xenoliths', sporadic garnet, green spinel, small amounts of pyroxene, and in the absence of andalusite. Read gives two analyses both of which show higher FeO and CaO

and lower Al_2O_3, Fe_2O_3, and MgO. Read now considers the Arnage type to be the result of an earlier, pre-gabbroic, migmatization.

Summary.—The Upington cordierite-rock is thought to be the result of the metasomatism of an original pelitic sediment whereby it gained alumina and magnesia and was converted into a rock containing porphyroblastic cordierite together with potash-felspar, oligoclase, biotite, andalusite, and quartz. This stage corresponds to the pyroxene-hornfels facies of Turner. At the height of the metamorphism it is possible that some of the andalusite was converted into sillimanite. With falling temperature, increased stress, and in the presence of excess water the above assemblage was unstable and retrogressive metamorphism took place. Equilibrium under the changed conditions was not attained, though there was a partial replacement of potash-felspar and andalusite by sericite and quartz and pinitization of the cordierite. The groundmass minerals took the stress while the large cordierites remained relatively unstrained. The tourmaline and apatite probably belong to this late metasomatic phase.

Acknowledgements.—The author would like to express her sincere appreciation to the following: Professor F. Walker for his keen interest, advice, and critical reading of the manuscript; Mr. H. C. G. Vincent for so kindly undertaking the analysis of the biotite and the FeO determination of the cordierite; Dr. A. Poldervaart for his generosity in providing me with the rock specimens and a partial separation of the biotite; Professor H. H. Read for most helpful discussion; Mr. A. O. Fuller for making the microphotographs; and the Division of Chemical Services, Pretoria, for the analysis of the rock and the cordierite.

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Manganese-iron garnet from Otjosondu, South-West Africa.[1]

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[Taken as read June 12, 1952.]

Introduction.

GARNETS rich in manganese and iron, associated with barium-felspars, have been reported by de Villiers[2] from the manganese ores of Otjosondu, South-West Africa, in which they occur as the most abundant silicate mineral. The farm Otjosondu is 80 miles NE. of Okahandja, a railway station on the line between Windhoek and Walvis.

One specimen (referred to as no. 1), of which de Villiers published a chemical analysis, is massive and of a somewhat dark-yellowish colour. The material is traversed by veinlets of hyalophane (Cn_9), about 0·5 mm. broad. The other specimen (referred to as no. 2) is medium to fine grained and of a dark-reddish colour. Grains of celsian (Cn_{94}) are evenly distributed throughout this sample. Under the microscope both garnets appear to be free from inclusions and other impurities.

Physical properties.

Both garnets are optically isotropic. Refractive indices were determined for sodium-light at room-temperature by the immersion method using phosphorus-bearing liquids as embedding media, and found to be: no. 1, n 1·872; no. 2, n 1·901 ($\pm$0·003).

Specific gravities were determined by suspension in Clerici solution. The results obtained were: no. 1, D_4^{16} 4·081; no. 2, D_4^{16} 3·962 ($\pm$0·005).

X-Ray examination.

X-ray powder diffraction patterns were obtained by using a 114·59 mm. diameter camera in which the film is mounted according to the Straumanis method.[3] The centres of the entrance and exit holes in the film were determined by measuring the lines on either side of these

[1] Published by permission of the Honourable, the Minister of Mines of the Union of South Africa.

[2] J. E. de Villiers, The manganese ores of Otjosondu, South-West Africa. Trans. Geol. Soc. South Africa, 1951, vol. 54, pp. 89–98. [M.A. 11–553.]

[3] M. E. Straumanis, Journ. Appl. Physics, 1949, vol. 20, p. 726.

holes in order to obtain check points from which a shrinkage correction factor was determined. The temperature during the exposure remained reasonably constant and did not vary more than 2° C. above room-temperature (22° C.). The films were allowed to dry for two weeks before measuring. The exposure time for both samples was 20 hours using cobalt radiation with an iron filter at 30 kV. and 10 mA. The samples were mounted in Lindemann glass capillary tubes of about 0·05 mm. diameter. Values for a were obtained according to the Bradley and Jay graphical extrapolation method, as described by Wasserstein of this Laboratory.[1]

TABLE I. X-ray intensities and spacings of garnets nos. 1 and 2 in Å.

		No. 1, a 11·819 (±0·003) Å.			No. 2, a 12·000 (±0·003) Å.		
No.	(*hkl*).	Int.	θ.	d (meas.)	Int.	θ	d (meas.)
1.	(400)	9	17·82°	2·92	9	17·52°	2·97
2.	(420)	10	19·94	2·62	10	19·68	2·66
3.	(422)	9	21·96	2·39	9	21·62	2·43
4.	(510) (431)	6	22·87	2·30	6	22·50	2·34
5.	(521)	6	24·66	2·14	6	24·27	2·18
6.	(611) (532)	8	28·00	1·906	8	27·55	1·934
7.	(444)	5	31·80	1·698	5	31·31	1·721
8.	(640)	9	33·23	1·632	9	32·73	1·654
9.	(642)	10	34·64	1·574	10	34·10	1·596
10.	(800)	7	37·37	1·474	7	36·83	1·492
11.	(840)	7	42·81	1·316	7	41·99	1·337
12.	(842)	7	44·05	1·288	7	43·31	1·304
13.	(644)	7	45·35	1·257	7	44·63	1·273
14.	(10.4.0)	6	54·76	1·095	6(α_1) 4(α_2)	53·68 53·90	1·110
15.	(10.4.2) (873)	6	56·16	1·077	6(α_1) 4(α_2)	55·02 55·24	1·092
16.	(880)	6	59·07	1·043	6(α_1) 4(α_2)	57·79 58·02	1·057
17.	(12.0.0) (884)	4	65·47	0·983	4(α_1)	63·67	0·998
18.	(12.2.0)	4	67·11	0·971	4(α_1)	65·26	0·985
19.	(12.2.2) (10.6.4)	9	69·03	0·968	9(α_1) 5(α_2)	67·01 67·31	0·972

Chemical properties and unit-cell contents.

The chemical analyses of the garnets were carried out on material separated by a Frantz isodynamic separator. The final material submitted for analysis contained less than 1 % impurities. The spectrographic analyses were done on selected fragments, which were examined

[1] B. Wasserstein, Precision lattice measurements of galena. Amer. Min., 1951, vol. 36, pp. 102–115. [M.A. 11–316.]

microscopically and found to be free from impurities, with the following results: No. 1—present, Si, Al, Fe, Mn, Ca, Mg; traces, Ba, Na, K; absent, Ti, Cr, Li, Rb, Cs, Be. No. 2—present, Si, Al, Fe, Mn, Ca, Mg; traces, Ba, Na; absent, Ti, Cr, K, Li, Rb, Cs, Be.

TABLE II. Chemical analysis of garnet no. 1.
(Analyst, C. F. J. van der Walt, in J. E. de Villiers, 1951.)

			Mol. ratios.			Atomic ratios.	Unit-cell contents.	
SiO_2	...	34·56	0·0579	Si	...	0·5759	23·64	24
Al_2O_3	...	4·72	0·0463	Al	...	0·0926	3·80	4
Fe_2O_3	...	22·96	0·1435	Fe	...	0·2870	11·79	12
MnO	...	22·12	0·3116	Mn	...	0·3116	12·79	13
MgO	...	0·56	0·0140	Mg	...	0·0140	0·57	11
CaO	...	14·60	0·2607	Ca	...	0·2607	10·70	
BaO	...	0·00	—	O	...	2·3075	94·73	96
		99·52						

TABLE III. Chemical analysis of garnet no. 2. (Analyst, P. L. le Roux.)

			Mol. ratios.			Atomic ratios.	Unit-cell contents.	
SiO_2	...	34·26	0·5710	Si	...	0·5710	23·89	24
Al_2O_3	...	5·98	0·0586	Al	...	0·1172	4·90	5
Fe_2O_3	...	22·20	0·1388	Fe	...	0·2776	11·61	12
MnO	...	13·29	0·1872	Mn	...	0·1872	7·83	8
MgO	...	0·67	0·0168	Mg	...	0·0168	0·70	18
CaO	...	22·74	0·4061	Ca	...	0·4061	16·98	
				O	...	2·3443	98·04	98
		99·14						

Garnet no. 1 conforms very closely to the ideal ratio of

$$3R''O.R_2'''O_3.3SiO_2.$$

It seems likely that in this case isomorphous replacement is restricted to atoms of the same valence. In the case of garnet no. 2 the ratio of 3:1:3 does not hold. Although it seems unlikely that any Al has replaced Si, it is obvious that there is an excess of $1R'''$, $2R''$, and 2 oxygen atoms.

The specific gravity of garnet no. 1 calculated from the X-ray data and the molecular weight (4142·49/8) is 4·07. In garnet no. 2, if the excess of $1R'''$, $2R''$, and 2 oxygen atoms in the unit cell did not occupy positions in the unit-cell it would not have had any influence on a, and consequently would not affect the calculated specific gravity, and there would be three possibilities of assembling the unit-cell contents, viz.:

	Mol. wt.	Sp. gr.
1. 24Si, 5Al, 11Fe, 17Ca, 7Mn, and 96O	4025·19/8	3·78
2. 24Si, 5Al, 11Fe, 18Ca, 6Mn, and 96O	4010·33/8	3·76
3. 24Si, 5Al, 11Fe, 16Ca, 8Mn, and 96O	4040/8	3·80

These calculated specific gravities are in very poor agreement with the measured value of 3·96. However, if the contents of the unit cell are taken as 24Si, 5Al, 12Fe, 18Ca, 8Mn, and 98O, yielding a molecular weight of 4208·07/8, the calculated specific gravity is 3·95, which agrees very well with the experimental value of 3·96. Therefore it seems reasonable to believe that the excess atoms occupy positions in the unit cell. The presence of excess atoms in the unit cell may also be regarded as a probable cause of the higher refractive index of garnet no. 2 as compared to no. 1, in spite of the fact that it contains less manganese.

If the packing indices of both garnets are determined according to the formula[1] P.I. = (volume of ions)/(volume of unit cell) × 10, it is found that both garnets have a P.I. of 6·3. Fairbairn lists the following: almandine 6·6, andradite 6·1, grossular 6·4, pyrope 6·5, spessartine 6·5. From a purely geometrical viewpoint there are cavities in the garnet structure which may provide accommodation for the above-mentioned excess atoms. For the determination of the volume of the ions in the unit cell the values of ionic volumes used are those listed by Fairbairn.

Norm calculations of the garnets.

In both garnets, with low alumina, the excess of manganese cannot be accounted as spessartine, and the presence of the molecule $3MnO.Fe_2O_3.3SiO_2$ is clearly indicated. To this garnet molecule Fermor[2] in 1909 applied the name *calderite*, a name that had been previously given by Piddington[3] to a 'silico iron and manganese rock' from India. Piddington's unsatisfactory analysis (SiO_2 46·35, Al_2O_3 0·35, Fe_2O_3 30·18, MnO 21·00, CaO 1·00, As 0·20) was interpreted by Mallet[4] as a massive Fe-Mn garnet with admixed quartz. Dana,[5] who had evidently not seen this analysis, classified calderite as a variety of andradite.

The norms for each garnet can be calculated in many ways, depending upon the relative amounts of grossular and spessartine in each case. The presence of grossular increases the resulting amount of calderite at the expense of andradite, while the presence of spessartine decreases the calderite content and causes an increase in the amount of andradite.

[1] W. H. Fairbairn, Packing in ionic minerals. Bull. Geol. Soc. Amer., 1943 vol. 54, p. 1035. [M.A. **9**–41.]

[2] L. L. Fermor, Mem. Geol. Surv. India, 1909, vol. 37, p. 182; Rec. Geol. Surv. India, 1926, vol. 59, p. 204. [Min. Mag. **21**–558; M.A. **3**–308.]

[3] H. Piddington, Journ. Asiatic Soc. Bengal, 1851, vol. 19 (for 1850), p. 145.

[4] F. R. Mallet, Geology of India, pt. 4, mineralogy, 1887, p. 90.

[5] J. D. Dana, System of mineralogy. 5th edit., 1868, p. 443.

Only these extreme cases where the maximum quantities of grossular (norm A) and spessartine (norm B) are formed, will be considered.

TABLE IV. Norm A of garnet no. 1, calculated with all Mn as calderite.

	Mol. ratios.	Pyrope.	Grossular.	Andradite.	Calderite.	Residue.
SiO_2 ...	0·5759	0·0140	0·1248	0·1359	0·2946	0·0066
Al_2O_3 ...	0·0463	0·0047	0·0416	—	—	—
Fe_2O_3 ...	0·1435	—	—	0·0453	0·0982	—
MnO ...	0·3116	—	—	—	0·2946	0·0170
MgO ...	0·0140	0·0140	—	—	—	—
CaO ...	0·2607	—	0·1248	0·1359	—	—
Weight %	...	1·89	18·72	23·02	54·30	= 97·93

TABLE V. Norm B of garnet no. 1, calculated with all Ca as andradite.

	Mol. ratios.	Pyrope.	Spessartine.	Andradite.	Calderite.	Residue.
SiO_2 ...	0·5759	0·0140	0·1248	0·2607	0·1698	0·0066
Al_2O_3 ...	0·0463	0·0047	0·0416	—	—	—
Fe_2O_3 ...	0·1435	—	—	0·0869	0·0566	—
MnO ...	0·3116	—	0·1248	—	0·1698	0·0170
MgO ...	0·0140	0·0140	—	—	—	—
CaO ...	0·2607	—	—	0·2607	—	—
Weight %	...	1·89	20·59	44·14	31·31	= 97·93

TABLE VI. Norm A of garnet no. 2, calculated with all Mn as calderite.

	Mol. ratios.	Pyrope.	Grossular.	Andradite.	Calderite.	Residue.
SiO_2 ...	0·5710	0·0168	0·1431	0·2292	0·1872	—0·0053
Al_2O_3 ...	0·0586	0·0056	0·0477	—	—	0·0053
Fe_2O_3 ...	0·1388	—	—	0·0764	0·0624	—
MnO ...	0·1872	—	—	—	0·1872	—
MgO ...	0·0168	0·0168	—	—	—	—
CaO ...	0·4061	—	0·1431	0·2292	—	0·0338
Weight %	...	2·25	21·47	38·81	34·50	= 97·03

TABLE VII. Norm B of garnet no. 2, calculated with all Ca as andradite.

	Mol. ratios.	Pyrope.	Spessartine.	Andradite.	Calderite.	Residue.
SiO_2 ...	0·5710	0·0168	0·1432	0·4061	0·0102	—0·0053
Al_2O_3 ...	0·0586	0·0056	0·0477	—	—	0·0053
Fe_2O_3 ...	0·1388	—	—	0·1354	0·0034	—
MnO ...	0·1872	—	0·1432	—	0·0102	0·0338
MgO ...	0·0168	0·0168	—	—	—	—
CaO ...	0·4061	—	—	0·4061	—	—
Weight %	...	2·25	23·61	68·78	1·87	= 96·51

In deciding between these two possibilities guidance is provided by the specific gravities calculated from the cell dimensions as given by Bragg[1] (table VIII, with the addition of calderite).

[1] W. L. Bragg, Atomic structure of minerals. Cornell Univ., 1937. [M.A. 7–7.]

TABLE VIII. Garnet group.

Garnet.	Formula.	*a*.	Mol. wt.	Sp. gr.
Pyrope	$3MgO.Al_2O_3.3SiO_2$	11·51 Å.	403·1	3·43
Almandine	$3FeO.Al_2O_3.3SiO_2$	11·50	497·6	4·25
Spessartine	$3MnO.Al_2O_3.3SiO_2$	11·60	494·9	4·12
Grossular	$3CaO.Al_2O_3.3SiO_2$	11·83	450·4	3·53
Uvarovite	$3CaO.Cr_2O_3.3SiO_2$	11·95	500·2	3·81
Andradite	$3CaO.Fe_2O_3.3SiO_2$	12·02	508·1	3·80
Calderite	$3MnO.Fe_2O_3.3SiO_2$	11·82	552·7	4·42

By taking the specific gravity of garnet no. 1 as 4·08 and no. 2 as 3·96, and referring to the two norms A and B of each of the two garnets, the specific gravity of the calderite molecule can be calculated and from the values obtained it can be decided which one of the two norms is more likely to be correct. The results are given below:

	Sp. gr.
Garnet no. 1, Norm A	4·42
Norm B	4·49
Garnet no. 2, Norm A	4·44
Norm B	6·09

By comparing these values it seems reasonable to believe that the specific gravity of pure calderite is 4·42, and in the case of both garnets the norm A is therefore correct. The unit-cell dimension of pure calderite was calculated as 11·82 Å. (mol. weight of calderite being 552·7), which seems acceptable when the unit-cell dimensions and specific gravities of calderite and andradite are compared. The molecular weight of MnO is higher than that of CaO and the ionic radius of Mn (0·91 Å.) is smaller than that of Ca (1·06 Å.), so therefore one would expect a higher specific gravity and a smaller unit cell for calderite as compared with that of andradite. Taking the unit cell for pure calderite as *a* 11·82 Å., then its packing index can be calculated as 6·2.

Acknowledgements.—The author wishes to thank Dr. J. N. van Niekerk of the Scientific and Industrial Research Board, Pretoria, for taking the X-ray patterns, and Dr. J. E. de Villiers of the Geological Survey, Pretoria, who first identified these minerals and kindly handed them to the author for further investigation. Professor B. V. Lombaard, of the University of Pretoria, critically reviewed the manuscript; the author is indebted to him for many useful suggestions.

Synthetic soda-free thomsonite.

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[Taken as read June 12, 1952.]

X-RAY powder photographs reveal thomsonite as the principal product of some low-temperature hydrothermal experiments. Glasses of three compositions were used as starting materials; one of the composition of anorthite ($CaAl_2Si_2O_8$), one of a gallium-containing anorthite[1] ($Ca_4[Ga_3Al_5]Si_8O_{32}$) in which $\frac{3}{8}$ of the Al is replaced by Ga, and a glass of the oxide composition of zoisite minus the water ($4CaO.3Al_2O_3.6SiO_2$).

The Na:Ca and Al:Si ratios in natural thomsonite vary between the extremes expressed in the formulae $Na_3Ca_9Si_{19}Al_{21}O_{80}.24H_2O$ and $Na_7Ca_5Si_{23}Al_{17}O_{80}.24H_2O$ according to A. N. Winchell,[2] and M. H. Hey.[3] E. T. Wherry,[4] on the basis of the available analytical data, regarded thomsonite to be of fixed composition ($NaCa_2Al_5Si_5O_{20}.6H_2O$) and noted that the name comptonite had priority for a supposedly soda-free or soda-poor 'variety'. Hey's later X-ray, optical, and chemical data disprove Wherry's views, and for the most part support Winchell's suggestions as to solid solution in thomsonite, chiefly that of concurrent Na–Ca and Al–Si interchanges as in the plagioclase felspars. In 1924 Gordon[5] proposed a compositional range for thomsonite with $CaAl_2Si_2O_8.3H_2O$ as an end-member, but Winchell (1925) discards Gordon's formulations as being very unlikely as regards solid-solution possibilities.

The synthetic products here produced from the several glasses are soda-free; the glasses were melted from reagent-grade oxides and reacted hydrothermally with distilled water in stainless steel pressure vessels.

[1] J. R. Goldsmith, Gallium and germanium substitutions in synthetic feldspars. Journ. Geol. Chicago, 1950, vol. 58, pp. 518–536. [M.A. **11**–326.]

[2] A. N. Winchell, A new theory of the composition of the zeolites. Amer. Min., 1925, vol. 10, pp. 88–97, 166–174. [M.A. **3**–13.]; Elements of optical mineralogy. Fourth edition, 1951, pt. 2. [M.A. **11**–463.]

[3] M. H. Hey, Studies on the zeolites. Part II. Thomsonite (including faroelite) and gonnardite. Min. Mag., 1932, vol. 23, pp. 51–125.

[4] E. T. Wherry, Note on the composition of thomsonite. Amer. Min., 1923, vol. 8, pp. 121–125. [M.A. **2**–302.]

[5] S. G. Gordon, The composition of thomsonite. Proc. Acad. Nat. Sci. Philadelphia, 1924, vol. 76, pp. 103–107. [M.A. **2**–528.]

If one uses Winchell's formulation, but replaces all Na by Ca (and adjusts the Al:Si ratio to fit), the formula reduces to $Ca_3Al_6Si_4O_{20}.6H_2O$. The precise compositions of the synthetic products cannot be stated with certainty, and it is not definitely known that the material in question can be represented by the above formula. If the Al:Si ratio remained 1:1, as it was in the original batch ingredients, the soda-free nature would necessitate a greater number of vacant cation sites than are evident from the structural determination of Taylor et al.[1] The structure was determined on the basis of a unit cell containing four molecules of

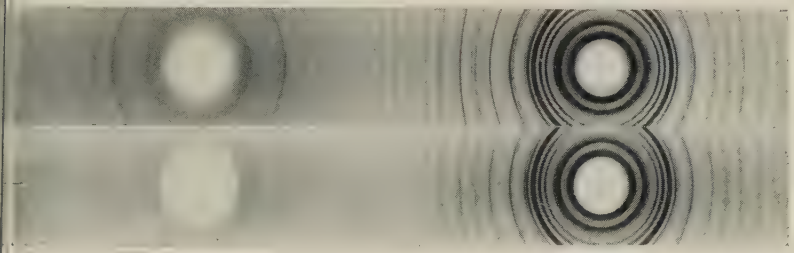

FIG. 1. X-ray diffraction powder photographs, Cu-$K\alpha$ radiation, 57·3 mm. diameter camera.

Upper photograph: thomsonite from Table Mt., Colorado.

Lower photograph: synthetic soda-free, Ga-bearing thomsonite ($\frac{3}{8}$ of the Al replaced by Ga).

$NaCa_2Al_5Si_5O_{20}$ (plus water), whereas if this fixed Al:Si ratio is maintained in the soda-free thomsonite, the formula would be $Ca_{2\frac{1}{2}}Si_5Al_5O_{20}$ (plus water). This would correspond to anorthite$+H_2O$ in composition, which is the end-member suggested by Gordon.

To determine precisely the composition would require synthesis of crystals sufficiently large so that the absence of extraneous phases could be established. This was not attempted; in fact, the material here described was so very fine-grained that ordinary optical examination was fruitless.

The H_2O content of the synthetic products is unknown, as are the pressure, temperature, and composition limits of the thomsonite stability field. It is perhaps of interest to note that if the composition is correctly expressed by the formula $Ca_3Al_6Si_4O_{20}.6H_2O$, the Al:Si ratio is 1·5; this is rather unusual in network silicates, as this ratio, particularly in natural minerals, ordinarily fails to exceed unity.

[1] W. H. Taylor, C. A. Meek, and W. W. Jackson, The structures of the fibrous zeolites. Zeits. Krist., 1933, vol. 84, pp. 373–398. [M.A. 5–354.]

Fig. 1 shows X-ray powder diffraction photographs of a natural thomsonite and of a synthetic soda-free, gallium-bearing product. As would be expected, the unit cell of the latter is somewhat larger than that of normal thomsonite. This material was crystallized at 245° C. and at 8000 psi (H_2O pressure), somewhat above the temperatures used for the Ga-free thomsonite syntheses. Unless the composition of this compound is the same as anorthite (plus water), an extraneous phase or phases should be present. For example, if the composition were $Ca_3Al_6Si_4O_{20}.6H_2O$ (including the Ga with the Al), excess SiO_2 (unless leached out of the sample) would be present after crystallization from a composition initially that of anorthite. No diffraction lines other than those belonging to the thomsonite pattern are apparent on the film from which the photograph of fig. 1 was made. Although even a moderately small content of crystalline SiO_2 might be expected to yield lines in this film, the absence of these lines, although suggestive, does not prove that the composition is equivalent to a hydrated anorthite.

Acknowledgement.—Thanks are due to Dr. M. H. Hey for his examination of the powder pattern of the Colorado thomsonite, and for his comments on the composition and properties of thomsonite.

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The identity of cryptomorphite and ginorite.

By M. H. Hey, M.A., D.Sc., and F. A. Bannister, M.A., Sc.D.

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[Read March 27, 1952.]

HENRY HOW, professor of chemistry and natural history in the University of King's College, Windsor, Nova Scotia, described in 1861 the occurrence of a new calcium sodium borate, which he named cryptomorphite from the microscopic size of the crystals.[1] The mineral was found in narrow seams of mirabilite (glauber-salt) at the junction of anhydrite and gypsum in Clinton quarry, Windsor, where he had also discovered ulexite in 1857.[2] The cryptomorphite occurred as inclusions about the size of a small bean, between the gypsum and crystals of mirabilite.

The powder pattern and spacing data of a specimen labelled cryptomorphite from Windsor, purchased from Professor C. U. Shepard in 1860, were found in 1944 to be quite different from those of ulexite. It was subsequently pointed out to us, both by Dr. W. T. Schaller and Mr. N. R. Goodman who also were interested in this mineral, that this specimen (B.M. 40260) is principally anhydrous sodium sulphate. It is not surprising, therefore, that its powder pattern should be quite different from that of ulexite. Powder photographs, taken in the Mineral department, of further samples from B.M. 40260 and from a larger amount of white powder also labelled cryptomorphite B.M. 52546 and purchased from How himself in 1879, led to the same conclusion. The main constituent of both these was derived from mirabilite, which under the normal conditions of storage in a museum would certainly dehydrate to thenardite.

So far, chemical, optical, and X-ray powder photographs had not revealed the presence of a borate in either specimen. A small sealed tube found with B.M. 52546 in 1934 and registered as B.M. 95939 was

[1] H. How, Natro-boro-calcite and another borate occurring in the gypsum of Nova Scotia. Amer. Journ. Sci., 1861, ser. 2, vol. 32, pp. 9–13; Edinburgh New Phil. Journ., 1861, vol. 14, pp. 112–116. Contributions to the mineralogy of Nova Scotia. Min. Mag., 1877, vol. 1, pp. 257–260.

[2] H. Haw [i.e. How], On the occurrence of natro-boro-calcite with glauber-salt in the gypsum of Nova Scotia. Amer. Journ. Sci., 1857, ser. 2, vol. 24, pp. 230–235.

the last specimen to be examined and this yielded a powder pattern easily distinguished from those of thenardite and ulexite.

In the meantime, Dr. Schaller had examined a supposed ginorite from Sasso Pisano, Lardarello, Tuscany, and identified it as priceite. We also found only priceite on a specimen labelled ginorite (B.M. 1934,980), which had been sent to the department by Prince Piero Ginori Conti. At this stage, the status of ginorite as a mineral species seemed uncertain, although, on the basis of the chemical analyses of cryptomorphite and ginorite, one of us had suggested the possible identity of the two minerals.[1] Fortunately, Professor S. Bonatti of Pisa was able to send us sufficient of the original ginorite for chemical and X-ray examination and this gives the same powder pattern as cryptomorphite (B.M. 95939) already mentioned. G. D'Achiardi's optical data[2] for ginorite clearly distinguishes it from priceite and gives 78° as the angle of the cleavage rhomb plates, close to Robb's measurement of 80° for cryptomorphite as recorded by H. How in 1861. The X-ray powder data given in table III also clearly distinguishes ginorite and priceite.

TABLE I. Chemical analyses of ginorite and cryptomorphite.

	1.	2.	3.	4.	5.	6.
B_2O_3 ...	63·00	64·06	58·54	63·64	53·98	65·5
CaO ...	15·40	16·00	14·75	16·03	14·21	17·0
MgO ...	—	—	—	—	0·62	—
Na_2O ...	—	—	0·16	0·17	7·25	—
SO_3 ...	—	—	—	—	3·98	—
H_2O ...	19·40	19·27	18·54	20·16	19·96*	17·5
CO_2 ...	—	0·15	—	—	—	—
insol. ...	2·20	1·07	8·34	—	—	—
	100·00	100·55	100·33	100·00	100·00	100·0

1. Ginorite, Sasso Pisano, Tuscany. Analyst, — Gallori (G. D'Achiardi, 1934).
2. „ „ „ „ Analyst, P. Rossoni (G. D'Achiardi, 1934).
3. „ „ „ „ Analyst, M. H. Hey, 1951. B.M. 1952, 89. An X-ray powder photograph identifies the insoluble residue as a mixture of quartz and muscovite.
4. Analysis 3 recalculated to 100 %, after deducting insolubles.
5. Cryptomorphite, Windsor, Nova Scotia. Analyst, H. How, 1861. * Probably includes some SO_3.
6. Analysis 5 recalculated to 100 %, after deducting 16·60 % thenardite (equivalent to 7·25 % Na_2O).

The chemical data given in table I are not, taken by themselves, conclusive of the identity. The new analysis of ginorite made on the material

[1] M. H. Hey, An index of mineral species & varieties arranged chemically. London, 1950, p. 65.

[2] G. D'Achiardi, Ginorite, nuovo borato di calcio di Sasso Pisano. Periodico Min. Roma, 1934, vol. 5, pp. 22–32. [M.A. 5–484.]

sent by Prof. Bonatti confirms the mineral to be a hydrated calcium borate; our analysis approaches that of P. Rossoni, after deduction of insoluble material. Table II summarizes the optical data now available for cryptomorphite and ginorite.

TABLE II. Optical data for cryptomorphite and ginorite.

Locality.	Refractive index.	Mean size.	Shape.	Observer.
Nova Scotia	Not measured	0·12 mm.	Thin rhomb plates '80° or more'	Robb
Nova Scotia	n_1~1·526 n_2~1·579	0·015	Thin rhomb plates with sharp outline, 79°	F. A. B.
Tuscany	α 1·517 β 1·524 γ 1·577 $2V_\gamma$ 42°±2°	~0·1	Compact, yielding cleavage flakes some with 78°	D'Achiardi
Tuscany	n_1~1·526 n_2~1·579	~0·05	Compact, yielding cleavage flakes some with 77°	F. A. B.

Note. The longer diagonal of the rhomb plates has positive elongation, and so far I have noticed the extinction directions always bisect the angles of the 'cryptomorphite' crystals and the rhomb cleavage flakes of ginorite. The symmetry of ginorite may perhaps be orthorhombic, not monoclinic, as D'Achiardi supposed.

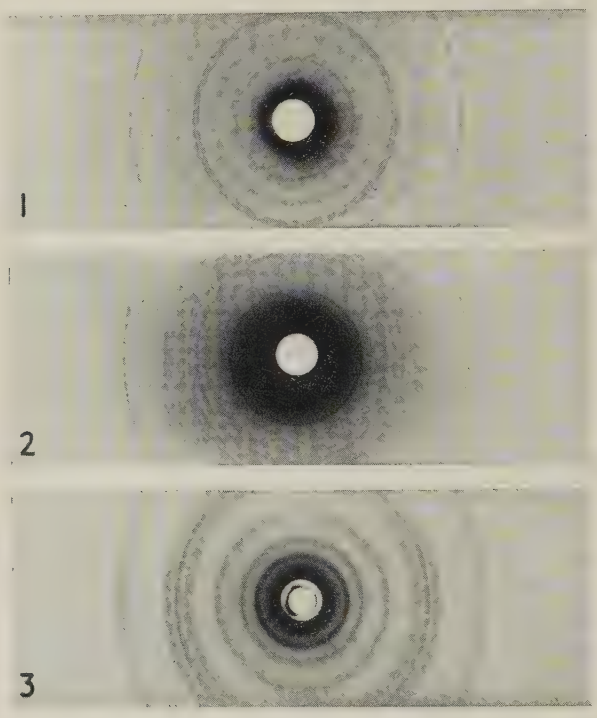
TABLE III. X-ray powder data for ginorite and priceite.

Ginorite, Tuscany.				Priceite, Oregon.			
I.	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*	*d.*
vs	7·18 Å.	vw	2·62 Å.	vvs	10·91 Å.	vvw	2·53 Å.
s	5·36	vvw	2·58	ms	5·96	mw	2·47
vw	4·92	vvw	2·53	mw	5·47	vw	2·41
w	4·68	vw	2·47	vvw	4·86	m	2·31
vvw	4·29	vwb	2·36	w	4·51	vvw	2·24
w	4·08	vw	2·28	w	4·30	ms	2·18
mw	3·90	w	2·24	m	3·67	vw	2·06
mb	3·57	w	2·16	ms	3·49	vw	2·02
vvw	3·42	s	2·09	w	3·38	vw	1·98
m	3·28	vw	2·03	vvw	3·07	mw	1·94
vvw	3·18	wb	1·96	vw	2·97	vw	1·876
mw	3·12	vvw	1·92	w	2·89	w	1·855
w	2·98	vvw	1·821	mw	2·79	wb	1·807
w	2·88			w	2·73	vw	1·758
vw	2·81			w	2·68	w	1·730
vw	2·73			vw	2·60		

These measurements of spacings and intensities (figs. 1 and 2) were obtained in a cylindrical camera, diameter 6 cm. with filtered copper radiation, Cu-$K\alpha$, 1·542 Å.

H. How's analysis of cryptomorphite should not be rejected entirely, although there is little doubt that it is an analysis of a mixture, and its

interpretation is not quite clear. On the one hand, the observed SO_3 is not sufficient to form thenardite with all the Na_2O, while, on the other, the evidence from the Italian material appears to indicate that the borate present contains little or no alkali. However, owing to shortage



Figs. 1–3. Powder photographs of calcium borate minerals. 1. Priceite, Curry Co., Oregon, U.S.A. 2. Ginorite, Sasso Pisano, Tuscany. 3. Ulexite, Iquique, Tarapacá, Chile.

All three were taken in a 6-cm. diameter camera with filtered copper radiation Cu-$K\alpha$, 1·542 Å.

of material, How necessarily determined H_2O by ignition and the other constituents on the ignited residue. Direct experiments showed that when Na_2SO_4 is fused with borax and excess B_2O_3 an appreciable amount of SO_3 is volatized, and it therefore appears probable that How's SO_3 figure is low, and his H_2O correspondingly high. Assuming that the soda is wholly present as thenardite, there would be 16·60 % of the latter, and the last column of table I shows that after deduction of this, How's analysis is in fair agreement with Rossoni's and Hey's analyses of

ginorite. It is clear from How's papers that he was at pains to distinguish cryptomorphite from both priceite and ulexite, with which minerals it was confused in his day. He was, however, confident that the mineral contains sodium; though this is not confirmed by our new analysis.

In our opinion, the X-ray powder pattern, the crystal shape, and the optical properties constitute proof of the identity of cryptomorphite and ginorite. We suggest that the name ginorite should be used, rather than cryptomorphite, for the mineral from Nova Scotia, as well as from Tuscany, since the Nova Scotia material was never isolated in a pure state and because hardly any of it seems to have been preserved.

A re-examination of tobermorite.

By G. F. Claringbull, B.Sc., Ph.D., F.G.S.
and M. H. Hey, M.A., D.Sc.

Department of Mineralogy, British Museum.

[Read June 12, 1952.]

TOBERMORITE, a hydrated silicate of calcium, was described by M. F. Heddle in 1880[1] from three Scottish localities: two near Tobermory in the island of Mull, and the third a quarry near the pier at Dunvegan in Skye. Further localities for the mineral are Sgùrr nam Boc, Loch Eynort in Skye,[2] and Ardtornish Bay in Morven (Morvern), Argyllshire.[3]

Because of marked similarity in chemical composition it has been suggested that tobermorite might be identical with gyrolite.[4] In view of this and of the current interest in hydrated calcium silicates in cement chemistry the species has been re-examined. Three specimens, all originally in the Heddle collection of the Royal Scottish Museum, have been studied. They represent the two Mull localities (S.M. 435 A1 and A2) and Loch Eynort in Skye (B.M. 1937,1490) and agree closely with the Heddle descriptions. In two cases, north of Tobermory pier and Loch Eynort, the amygdale in which the mineral occurs is lined as noted by Heddle with a colourless zeolite now found from X-ray rotation photographs about the needle axis in each case to be thomsonite. The mass of pinkish tobermorite in all cases consists of a very compact, fine-grained aggregate of minute birefringent units (average size of crystals about 0·002 cm. diameter) with a mean refractive index of $1{\cdot}558 \pm 0{\cdot}003$.

X-ray powder photographs from small fragments of each specimen gave a consistent pattern (table I) which could not be matched with that of any available data for natural material. They differed in particular from gyrolite. A comparison with data for crestmoreite showed some resemblance. This led to comparison with 'calcium silicate

[1] M. F. Heddle, Min. Mag., 1880, vol. 4, p. 119.
[2] M. F. Heddle, Trans. Geol. Soc. Glasgow, 1893, vol. 9, p. 254.
[3] J. Currie, Min. Mag., 1905, vol. 14, p. 93.
[4] E. S. Dana, System of mineralogy. 6th edit., 1892, p. 570; M. H. Hey, Chemical index of minerals, 1950, p. 91.

hydrate (I)'.[1] The latest data for the latter, kindly supplied by Dr. H. F. W. Taylor, are given in table I and show a close match.

TABLE I. X-ray powder data for tobermorite in Å.

Tobermorite						'Calcium silicate hydrate (I)'.	
Tobermory pier, Mull.		Bloody Bay, Mull.		Loch Eynort, Skye.			
I.	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*	*d.*
vvs	11·4	s	11·3	vvs	11·2	s	11
mw	5·47	m	5·44	m	5·46	ms	5·6
—	—	—	—	vvw	4·23	—	—
mw	3·50	vvw	3·52	mw	3·54	vvw	3·55
vw	3·34	w	3·37	vw	3·31	vvw	3·28
s	3·10	ms	3·08	vs	3·10	vvs	3·07
m	2·99	m	2·96	ms	2·98	s	2·97
ms	2·82	mb	2·82	ms	2·82	s	2·80
vvw	2·74	vvw	2·71	vvw	2·72	—	—
vw	2·52	vvw	2·50	wb	2·52	vw	2·52
vw	2·45	vvw	2·43	vw	2·44	vw	2·48
wb	2·30	wb	2·29	mwb	2·29	ms	2·28
—	—	vvw	2·18	—	—	—	—
w	2·15	vw	2·14	w	2·14	m	2·15
vw	2·09	vw	2·08	w	2·09	m	2·07
mw	2·01	mw	2·00	mw	2·00	m	2·00
—	—	vvw	1·95	—	—	vvw	1·93
m	1·847	mb	1·836	ms	1·844	vs	1·83
—	—	—	—	—	—	vvw	1·81
—	—	vvw	1·731	vvw	1·768	vvw	1·76
				vvwb	1·731	vvw	1·71
mw	1·673	mw	1·667	mw	1·670	s	1·67
vw	1·622	—	—	w	1·624	vw	1·61
—	—	vw	1·565	—	—	vvw	1·59
w	1·550	w	1·540	w	1·545	m	1·53
vvw	1·503	—	—	vvw	1·508	—	—
vw	1·442	—	—	vw	1·440	vw	1·43
vvw	1·402	—	—	vw	1·401	w	1·405
						w	1·395
vvw	1·380	—	—	vw	1·380	vvw	1·370
vvw	1·290	—	—	—	—	—	—
vvw	1·268	—	—	—	—	—	—
vvw	1·258	—	—	—	—	vvw	1·260
vvwb	1·220	—	—	—	—	vw	1·225
vvw	1·185	—	—	—	—	vvw	1·185
vvw	1·170	—	—	—	—	vvw	1·160
vvwb	1·117	—	—	—	—	w	1·110
—	—	—	—	—	—	vw	1·075

Order of decreasing intensities: vvs, vs, s, ms, m, mw, w, vw, vvw, b = broad.
All photographs with Cu-$K\alpha$ radiation.

[1] Synthetic $CaSiO_3.aq.$–$Ca_3Si_2O_7.aq.$ H. F. W. Taylor, Journ. Chem. Soc. London, 1950, p. 3682; L. Heller and H. F. W. Taylor, ibid., 1951, p. 2397; 1952, p. 1018. [M.A. **11**–314, 471.]

It was decided to make a new analysis of the mineral and the Loch Eynort specimen was chosen. The result is shown in table II (column 3) compared with the two original analyses of Heddle.

TABLE II. Chemical analyses of tobermorite.

	1.	2.	3.		1a.	2a.	3a.
SiO_2 ...	46.508	46·62	46·17	Si ...	1·011	1·004	1·001
Al_2O_3 ...	2·402	3·895	4·26	Al ...	0·061	0·098	0·109
Fe_2O_3 ...	1·139	0·664	—	Fe‴ ...	0·018	0·010	—
FeO ...	1·853	1·080	0·15	Fe″ ...	0·034	0·019	0·003
MgO ...	0·474	—	trace	Mg ...	0·016	—	—
CaO ...	33·404	33·978	35·15	Ca ...	0·779	0·784	0·817
Na_2O ...	0·356	0·891	0·56	Na ...	0·014	0·038	0·007
K_2O ...	1·445	0·572	0·25	K ...	0·041	0·015	0·023
H_2O ...	12·606	12·109	13·47	H_2O ...	0·914	0·869	0·974
	100·187	99·81	100·01	ΣR ...	0·963	0·964	0·959

1. North of the pier, Tobermory, Isle of Mull. M. F. Heddle (1880).
2. Bloody Bay, Tobermory, Isle of Mull. Sp. gr. 2·423. M. F. Heddle (1880).
3. Loch Eynort, Skye. Sp. gr. 2·458 ±0·005. Analyst, D. I. Bothwell, on 1 gram of material.

1a, 2a, 3a. Analyses 1, 2, 3 recalculated to basis of O = 3.

The material used for this analysis shows on microscopic examination slight differences in appearance and refractive index which are related to small variations in macroscopic opacity, but otherwise shows no signs of the presence of a second phase. X-ray photographs of the different parts are identical. It appears then that the alumina and alkalis reported in all the analyses may be regarded not as due to impurities but as belonging to the tobermorite. But in view of the identity of the powder photographs of tobermorite and 'calcium silicate hydrate (I)' it would appear that neither the alumina nor alkali is an essential constituent of tobermorite, which may be formulated $CaSiO_3.H_2O$ with some replacement of 3Ca by 2Al and of Ca by $(Na,K)_2$. The 'calcium silicate hydrate (I)' of H. F. W. Taylor may therefore be regarded as synthetic tobermorite.

Note added in proof. Additional specimens have been examined from the Currie collection in the Grant Institute of Geology, University of Edinburgh, by kind permission of Prof. A. H. Holmes. Those from Bloody Bay and Loch Eynort are closely comparable with the material described above. Five small specimens from Sundelaget, Strömö, Faeroes, doubtfully referred to tobermorite (J. Currie, Trans. Edinburgh Geol. Soc., 1907, vol. 9, p. 37), were found to be gismondine.

Nacrite from Hirvivaara, northern Karelia, Finland.

(With Plate XXVIII.)

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Department of Geology

G. W. Brindley, Ph.D., F.Inst.P., and K. Hunter
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The University of Leeds.

[Taken as read June 12, 1952.]

I. Occurrence and general characters (O. v. K.)

Introduction.

Nacrite is the rarest member of the kaolin group of minerals. The name was first applied by Brongniart in 1807 to a mineral (talc granuleux of Haüy, 1801) the properties of which were not then adequately described. In 1832 Breithaupt recorded a mineral from an ore vein near Freiberg in Saxony, which has since been called nacrite. In the past, however, 'nacrite' has been applied quite frequently to different nacreous and micaceous minerals, not necessarily of kaolin composition, and the authenticity of the species was not definitely established until 1931 when Ross and Kerr,[1] on the basis of an X-ray study of nacrite from the locality Brand near Freiberg in Saxony, proved the mineral to be a distinct species of the kaolin group.

Apart from several occurrences in Saxony of which Brand is the type locality, nacrite has previously been recorded and confirmed only from St. Peter's Dome in the Pikes Peak district of Colorado, where it was originally described by Whitman Cross and W. F. Hillebrand[2] as a very pure kaolinite. In this latter occurrence the mineral is found as a well-crystallized alteration product of microcline in veins of obviously pegmatitic character, and is associated in the Eureka vein with the rare assemblage, fluorite, cryolite, columbite, zircon, astrophyllite, and mica. In the Freiberg localities, on the other hand, nacrite appears to be con-

[1] C. S. Ross and P. F. Kerr, The kaolin minerals. Prof. Paper U.S. Geol. Surv., 1931, no. 165-E, pp. 151–176. [M.A. 5–359.]

[2] W. Cross and W. F. Hillebrand, Minerals from the neighbourhood of Pikes Peak. Bull. U.S. Geol. Surv., 1885, no. 20, pp. 40–74.

fined to hydrothermal (quartz–galena) ore veins as one of the latest minerals to form.

The present find of nacrite was made by the writer in 1948, while mapping and prospecting Mount Hirvivaara in the area of Herajoki, Eno parish, northern Karelia, Finland. This region is occupied by pre-Cambrian rocks of the Karelian formation, which comprise quartzites, conglomerates, and intercalated andalusite-kyanite-chloritoid-sericite schists, penetrated in places by dolerite dikes. The quartzites, especially those of Hirvivaara, are strongly kyanite-bearing and locally, as on the hill Ilokallio, may contain patches of almost pure kyanite. On this hill nacrite occurs together with small perfect crystals of quartz and anatase, in cracks and cavities in an almost glassy, kyanite-bearing quartzite.

Attention was first attracted to the occurrence by the presence of small radial aggregates of an apple-green mineral of micaceous appearance, similar in general character to the pyrophyllite which is also found in the area. A preliminary chemical analysis, however, proved the mineral to have the composition of kaolinite. This first analysis (table I, anal. 1) showed an unusually high content of surface absorbed water, as determined at 110° C. on dry powdered material, and the coarsely crystalline habit of the kaolin mineral appeared moreover to indicate dickite or nacrite rather than kaolinite. X-ray powder photographs showed that the mineral was neither kaolinite nor dickite, but nacrite.

Petrographical aspects.

The nacrite, which is found in joints, cracks, and small pockets in the banded, kyanite-bearing quartzite, is coarsely crystalline in character and forms groups of radiating plates up to 5 mm. in diameter. When fresh and in compact masses, it is light green in colour, but otherwise appears colourless to yellow-brown. Usually quartz crystals line the walls of the cavities in which the nacrite occurs and in thin section are seen to be in optical continuity with the quartz grains in the surrounding quartzite. The nacrite occupies the central portion of the cavity and appears to have developed by outward growth from the cavity wall. Tiny excellent crystals of anatase are scattered sparingly amongst the nacrite, and a white, fine-grained, well-crystallized kaolinite (pl. XXVIII, figs. 1–3) fills the remainder of the cavity space.

The observed order of crystallization is quartz, nacrite, anatase, and kaolinite, but it is possible that some elongated low-temperature quartz crystals are of later formation than part of the nacrite. The first three minerals are primary, whereas the kaolinite has formed later and is

possibly of secondary origin. In the thin section the nacrite is colourless and non-pleochroic. Between crossed nicols (pl. XXVIII, fig. 1) it is seen to form fan-shaped or bunch-like twinned aggregates with low birefringence.

The bulk of the fine-grained crystalline kaolinite was lost in the preparation of the thin section, but some can still be observed enclosed in nacrite, where it forms excellent, minute, fan-shaped aggregates. The largest of these measures 0·2 mm. in diameter (pl. XXVIII, fig. 3).

The surrounding quartzite is a highly metamorphic kyanite-bearing type with a well-defined sutured texture (pl. XXVIII, fig. 4). A mineral separation showed the following accessory minerals: pyrite, rutile, monazite, apatite, zircon, and tourmaline.

It may be mentioned that in a patch of pure kyanite, almost in contact with the nacrite, the following minerals have been identified: diaspore, pyrophyllite, and kaolinite. Farther towards the NW., concentrations of pyrophyllite have been found in the quartzite and contain, in addition to corroded kyanite, relics of the rare mineral florencite, together with rutile, zircon, and tourmaline.

The entire complex of Hirvivaara thus appears to provide an interesting geological problem, as previously only a few localities with similar parageneses have been described from other parts of the world. In this connexion it may be pointed out that the minerals diaspore, florencite, pyrophyllite, and nacrite are new species for Finland.

Chemical composition and physical properties.

The kaolin minerals nacrite, dickite, and kaolinite are chemically identical and their composition corresponds closely to the chemical formula $Al_2O_3.2SiO_2.2H_2O$. A quantitative chemical analysis is consequently of limited value for the absolute identification of these minerals. So far three analyses of the Hirvivaara kaolin minerals have been carried out, two on the nacrite from Ilokallio and one on a kaolinite from a quartz-kyanite vein. The first analysis of nacrite (table I, anal. 1), a preliminary one, made in 1948 on hand-picked, ground material, showed a remarkably high content of hygroscopic water at 110° C. The second analysis, which was made later (1951) on hand-picked nacrite flakes, revealed, on the other hand, no surface absorbed water. A check on this matter was carried out. The nacrite flakes were ground and sieved through a 180-mesh silk sieve and the material thus obtained was exposed to the air for about 14 hours before H_2O- was determined. The water content was then found to be 2·70 %, or a value very similar to

that in anal. 1. It was further observed that the water could be driven off and reabsorbed reversibly.

Compared with earlier analyses of nacrite (table I, anal. 3–4) the present ones are very similar, especially anal. 2 which represents very pure material. The kaolinite analysis also corresponds very closely to the ideal formula. The Ti and Fe content is probably due to some traces of intermixed accessory minerals.

TABLE I. Chemical analyses of nacrite and kaolinite.

		1.	2.	3.	4.	5	6.
SiO_2	...	44·36	46·32	44·75	46·06	46·40	46·54
TiO_2	...	38·60	trace	—	—	0·18	—
Al_2O_3	...		39·65	39·48	39·63	39·15	39·50
Fe_2O_3	...		0·05	0·53	—	0·11	—
MnO	...	—	trace	—	—	—	—
MgO	...	—	trace	0·19	—	—	—
CaO	...	—	0·08	0·13	0·68	—	—
H_2O-	...	2·90	none	0·61	—	0·24	—
H_2O+(ign.)	...	14·48	14·21	14·40	13·77	13·98	13·96
		100·34	100·31	100·09	100·14	100·06	100·00

1. Nacrite in kyanite-quartzite, Hirvivaara, Finland. Analyst, O. von Knorring.
2. Nacrite in kyanite-quartzite, Hirvivaara, Finland. Analyst, O. von Knorring.
3. Nacrite in galena-quartz vein, Brand, Saxony. Analyst, F. A. Gonyer (in Ross and Kerr, 1931).
4. Nacrite in granite pegmatite, St. Peter's Dome, Pikes Peak, Colorado. Analyst, W. F. Hillebrand, 1885.
5. Kaolinite in kyanite-quartz vein, Hirvivaara, Finland. Analyst, O. von Knorring.
6. Theoretical composition for $Al_2O_3.2SiO_2.2H_2O$.

The refractive indices of the nacrite from Hirvivaara are shown in table II, together with the values determined for nacrites from other localities. The specific gravity determination was carried out with a Berman balance and the result represents the mean value of seven determinations.

TABLE II. Optical data of nacrite.

	α	β.	γ.	Sign.	Sp. gr.
1.	1·560	1·566	1·568 $\pm$0·002	negative	2·60$\pm$0·02
2.	1·557	1·562	1·563	negative	—
3.	1·560	1·563	1·566	positive, negative	—

1. Nacrite, Hirvivaara, Finland.
2. Nacrite, Brand, Saxony (Ross and Kerr, 1931).
3. Nacrite, St. Peter's Dome, Colorado (Ross and Kerr, 1931).

Dehydration of nacrite.

According to Richardson[1] it is generally misleading to regard the structural breakdown of the kaolin minerals as a function purely of temperature. The time of heating at various temperatures is an important factor. Samojlow[2] carried out some dehydration experiments on kaolinite (possibly dickite or nacrite) from cinnabar occurrences at Zaitsevo in Donets and found that the loss of total water in two hours at 525° C. was 7·63 %, and 12·99 % after 22 hours at the same temperature. It is very important, therefore, to know the exact conditions under which dehydration analyses have been carried out before comparisons of dehydration curves of kaolin minerals can be made. Ross and Kerr have shown that the kaolin minerals, kaolinite, dickite, and nacrite, have distinct dehydration curves, and that most of the water is lost between 400 and 525° C. in the case of kaolinite, between 500 and 600° C. in the case of dickite (1 sample only), and between 500 and 700° C. in the case of nacrite (2 specimens). Unfortunately the time of heating at different temperature intervals is not recorded by Ross and Kerr, nor is the state of the samples indicated (whether ground or unground). The two curves for nacrite given by these authors, although not identical, nevertheless show certain similarities. Thus the first break in the curve for nacrite from Brand is at about 460° C. and for nacrite from St. Peter's Dome at 550° C. The second break at about 675° C. is significant for both samples.

Two dehydration experiments were carried out on nacrite from the present occurrence, both ground and unground material being used. The specimens were heated in a platinum crucible in an electric furnace at 50° C. intervals over a range of temperatures for two hours each. The curves thus obtained are reproduced in text-fig. 1. In each determination 0·5 gram of material was used. The ground sample of nacrite was the same as that used in the determination of hygroscopic water. The dehydration curve obtained on this material was therefore made on a sample dried at 110° C. The coarse unground sample consisted of wedge-shaped nacrite flakes from 1 to 3 mm. in diameter. There is a considerable difference between these two curves although the major changes occur at approximately the same temperatures. In the range of 110–400° C

[1] H. M. Richardson, Phase changes which occur on heating kaolin clays. Chap. III *in* X-ray identification and crystal structures of clay minerals. Min. Soc., London, 1951.

[2] J. Samojlow, Über das Wasser des Kaolinits. Zeits. Kryst. Min., 1913, vol. 51, pp. 106–108.

the loss of water is almost nil for the coarse sample, whereas the fine one loses 2 % at 400° C. From this point the curves rise fairly steeply and the ground sample is seen to lose the bulk of its water between 400 and 500° C. During the same temperature interval the loss of water for the coarse sample is only about 1 %, the bulk of the water, that is 12 %, being lost between 500 and 600° C. Two definite breaks are recorded at about 650° C. and 750° C. respectively in both samples.

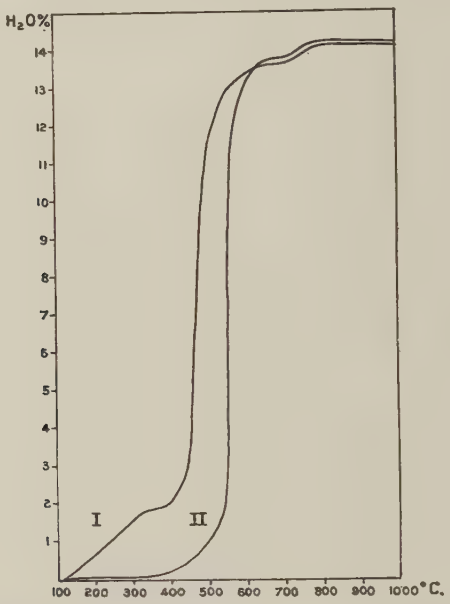


FIG. 1. Dehydration curves of nacrite (I, ground, II, unground) from Hirvivaara, Finland.

Conclusions.

The nacrite described in this paper occurs in association with quartz, anatase, and kaolinite as a cavity mineral in a highly metamorphosed kyanite-quartzite. The association is very different from those previously described and in many ways resembles the deposits of the alpine mineral veins formed in cavities and on joint surfaces. Nacrite has in fact been reported, although the identification has not been confirmed by X-ray data, by Koenigsberger[1] from Monti Camperio near Olivone,

[1] P. Niggli, J. Koenigsberger, and R. L. Parker, Die Mineralien der Schweizeralpen. Basel, 1940, p. 237. [M.A. 8–49.]

where it occurs as a filling in 'Anhydrit-Hohlprismen' in crystals of quartz.

As regards the origin of nacrite, Ross and Kerr believe that nacrite is probably formed by pneumatolytic or hydrothermal processes and that the temperature of formation is higher than in the case of kaolinite formed under similar conditions. The nacrite from Hirvivaara might well be of hydrothermal origin as there is evidence of widespread hydrothermal activity throughout the entire complex.

II. X-ray examination (G. W. B. and K. H.).

Rotation diagrams.

Several flakes, about 0·2 mm. in size, were carefully selected under a microscope and examined with Cu-$K\alpha$ radiation using a camera of 6 cm. diameter. Rotations were made about the *a*- and *b*-axes, and also about an axis normal to the cleavage plane, approximately the *c*-axis. The lattice parameters agreed with those previously given by Hendricks,[1] and in particular confirmed a *c*-axis spacing of about 43 Å. This corresponds to a unit cell containing six layers of the kind found in kaolinite. Rotation diagrams about the *b*- and *c*-axes are reproduced in pl. XXVIII.

All the rotation diagrams showed evidence of disorientation of the fragments composing the individual crystals. The disorientation, however, was not random but was similar to that observed with brucite and discussed by Brindley and Ogilvie.[2] On *a*- and *b*-axes rotation diagrams, some reflections are recorded as sharp spots, others are streaked along Debye-Scherrer arcs. The sharp spots correspond to reflections with the *l*-index zero (or small values). In *c*-axis rotation diagrams, all the reflections are extended along short arcs. As in the case of brucite, the results are consistent with some tilting of the *a*- and *b*-axes and with absence of rotation of these axes about *c*; they agree also with the appearance of the nacrite crystals shown in pl. XXVIII.

Powder diagrams.

Since relatively few occurrences of nacrite are recorded in the literature and since the X-ray data for this mineral are rather sparse, it was thought worth while to measure the powder diagram in detail. A 20 cm.

[1] S. B. Hendricks, The crystal structure of nacrite $Al_2O_3.2SiO_2.2H_2O$ and the polymorphism of the kaolin minerals. Zeits. Krist., 1939, vol. 100, pp. 509–518. [M.A. 7–422.]

[2] G. W. Brindley and J. G. Ogilvie, The texture of single crystals of brucite. Acta Cryst. (to appear), 1952.

diameter camera employing glancing-angle technique was used with both filtered Ni-$K\alpha$ and filtered Co-$K\alpha$ radiations. An internal calibration was based on reflections from a trace of quartz impurity and the quartz spacings were calculated from the parameters given by Wilson and Lipson,[1] namely a 4·9032, c 5·3937 kX. The nacrite was crushed rather than ground in order to minimize lattice distortion. A diagram obtained with Co-$K\alpha$ radiation is reproduced in pl. XXVIII. The lattice spacings and the visually estimated intensities of the reflections are listed in table III, where they are compared with data previously published by Ross and Kerr (1931, loc. cit.), Gruner,[2] and Nagelschmidt.[3] Lines which have been recorded but are probably due to impurities are listed at the bottom of each column. Powder data for nacrite from Augustusburg, Saxony, recorded in Report no. 7 of the American Petroleum Institute's Project no. 49, are in very poor agreement with other data and are therefore omitted; the strong low-order reflections appear to be split by specimen absorption and the high-order spacings are consistently low.

A particular feature of the nacrite diagram is that it is much poorer than diagrams normally obtained with dickite and kaolinite. The occurrence of a number of broad lines which are still not resolved with a 20 cm. diameter camera may arise, as Gruner suggested, from the presence of groups of lattice planes of similar but not identical spacings, which is in accordance with the β-angle given by Hendricks, viz. 90° 20′±10′. We have, however, resolved the very strong line previously recorded at about 2·416 kX (I = 10) into a doublet 2·433 (I = 7) and 2·392 (I = 7), and the line at $4{\cdot}40_5$ (I = 7) may also be a close doublet having a separation of about 0·04 kX. For the unresolved broad lines, we have measured the apparent spacings corresponding to their outer edges; these are indicated in column 1 of table III by the bracketed values and the letter B signifying 'band'.

The lattice constants given by Hendricks are a 8·94, b 5·14, c 43·0 = 6×7·17, β 90° 20′. The a and b parameters of kaolinite and dickite, a 5·14, b 8·93, are interchanged in nacrite and the medium–strong line observed at 1·485 kX, usually indexed as (060), now becomes

[1] A. J. C. Wilson and H. Lipson, The calibration of Debye-Scherrer X-ray powder cameras. Proc. Physical Soc., 1941, vol. 53, pp. 245–250.

[2] J. W. Gruner, The crystal structure of nacrite and a comparison of certain optical properties of the kaolin group with its structures. Zeits. Krist., 1933, vol. 85 pp. 345–354. [M.A. 5–474.]

[3] G. Nagelschmidt, Röntgenographische Untersuchungen an Tonen. 1934, Zeits Krist., vol. 87, pp. 120–145. [M.A. 6–136.]

TABLE III. X-ray powder data for nacrite.

1.		2.		3.		4.		5.	
d.	*I.*	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*	*d.*	*I.*
7·16	10	7·15	vs	7·15	vs	7·078	10	—	—
4·405	7	4·42	s	4·40	s	4·404	8	4·471	8
4·115	3	4·16	m	4·15	w	4·126	3	4·201	5
3·570	10+	3·59	vs	3·57	vs	3·579	9	3·621	9
3·053	1	3·07	w	3·06	w	3·042	1b	3·101	3
2·911	½	—	—	—	—	—	—	—	—
2·573 2·497	3B	2·54	m	2·538	m	2·537	1b	2·541	5
2·433 2·392	7 7	2·416	vs	2·413	vs	2·418 2·393	10 1–2	2·425	10
2·325	2	2·305	vw	—	—	—	—	2·335	4
2·233	½	—	—	—	—	2·263	½–1b	—	—
2·125 2·065	1B	2·100	m	2·095	w	2·069	1vb	2·095	4
1·978	½	—	—	—	—	—	—	1·980	5
1·937 1·897	2B	1·922	m	1·918	m	1·902	2–3vb	1·920	5
1·814	2	—	—	—	—	—	—	—	—
1·789	3	1·797	m	1·795	m	1·795	1	—	—
1·683 1·648	3B	1·676	w	1·672	vw	1·675	2i	1·671	5
1·614	½	1·618	w	1·610	vw	1·616	2b	—	—
1·485	5	1·489	s	1·486	s	1·486	8	1·480	9
1·459	1	1·466	w	1·462	w	1·455	4b	1·450	3
1·432	½	—	—	—	—	1·434	½–1	—	—
1·316	½	—	—	—	—	1·314	½	1·318	1
1·283	½	1·282	vw	—	—	1·284	1	1·273	4
1·264	½	1·270	w	1·272	w	1·263	3	—	—
1·226	½	—	—	—	—	1·230	2vb	1·230	2
						1·208	½–1	1·209	5
Some additional lines which may arise from impurities:									
4·24						3·928	2		
3·336		3·38	w	3·38	w	3·442	1b	3·371	4
2·452		1·740	vw	—	—	1·744	½–1	—	—
2·278	quartz	—	—	—	—	1·583	1	—	—
2·123	lines	1·372	m	1·366	w	1·358	1–2	1·368	4
1·538									
1·379									
1·285									

b = broad, vb = very broad, B = band, i = indistinct.

1. Present data. Nacrite from Hirvivaara, Finland. Filtered Ni- and Co-$K\alpha$ radiations; camera radius 10·0 cm. Spacings in kX.

2 and 3. Data by Nagelschmidt (1934). Nacrite from Freiberg, Saxony (2), and Kunnerstein, Augustusburg, Saxony (3). Filtered Cu-$K\alpha$ radiation; camera radius 2·88 cm. Spacings apparently in Å.

4. Data by Gruner (1933). Nacrite from Brand, Saxony. Unfiltered Fe-K radiation; camera radius 5·73 cm. Spacings in Å.

5. Data by Ross and Kerr (1931). Nacrite from Brand, Saxony, and Pikes Peak, Colorado. Filtered Mo-$K\alpha$ radiation. Spacings in Å.

(600) and this gives $a = 8{\cdot}91$. Assuming the following lines to be basal $00l$ reflections, the layer spacings given in parentheses are obtained: 7·16 (7·16); 3·570 (7·140); 2·392 (7·176); 1·789 (7·156); 1·432 (7·160). The mean layer-spacing is 7·158 kX. Since β is so near to 90°, the c parameter within the limits of experimental error is 7·16 kX. The b parameter is difficult to obtain accurately, but as in other similar layer minerals, it is probably closely equal to $a/\sqrt{3} = 5{\cdot}14$, and this agrees exactly with the value obtained from the b-axis rotation diagram.

Summary of X-ray results.—Single-crystal and powder analyses prove conclusively that the kaolin mineral from Hirvivaara, Finland, is nacrite; the six-layer structure discovered by Hendricks is confirmed. The powder diagram is resolved in somewhat greater detail than has previously been recorded. The lattice parameters are a 8·91, b 5·14, c 7·16 kX. Hendrick's value for β has not been modified.

Acknowledgement.—One of us (K.H.) is indebted to the Durham Co. Education Committee for the award of a post-graduate scholarship.

Explanation of Plate XXVIII.

Photomicrographs and X-ray photographs of nacrite from Hirvivaara, Finland.

Fig. 1. Bunch-like masses of nacrite and quartz crystals from a cavity in kyanite-quartzite. Crossed nicols. × 17.

Fig. 2. Kaolinite enclosed by nacrite and quartz. Crossed nicols. × 27.

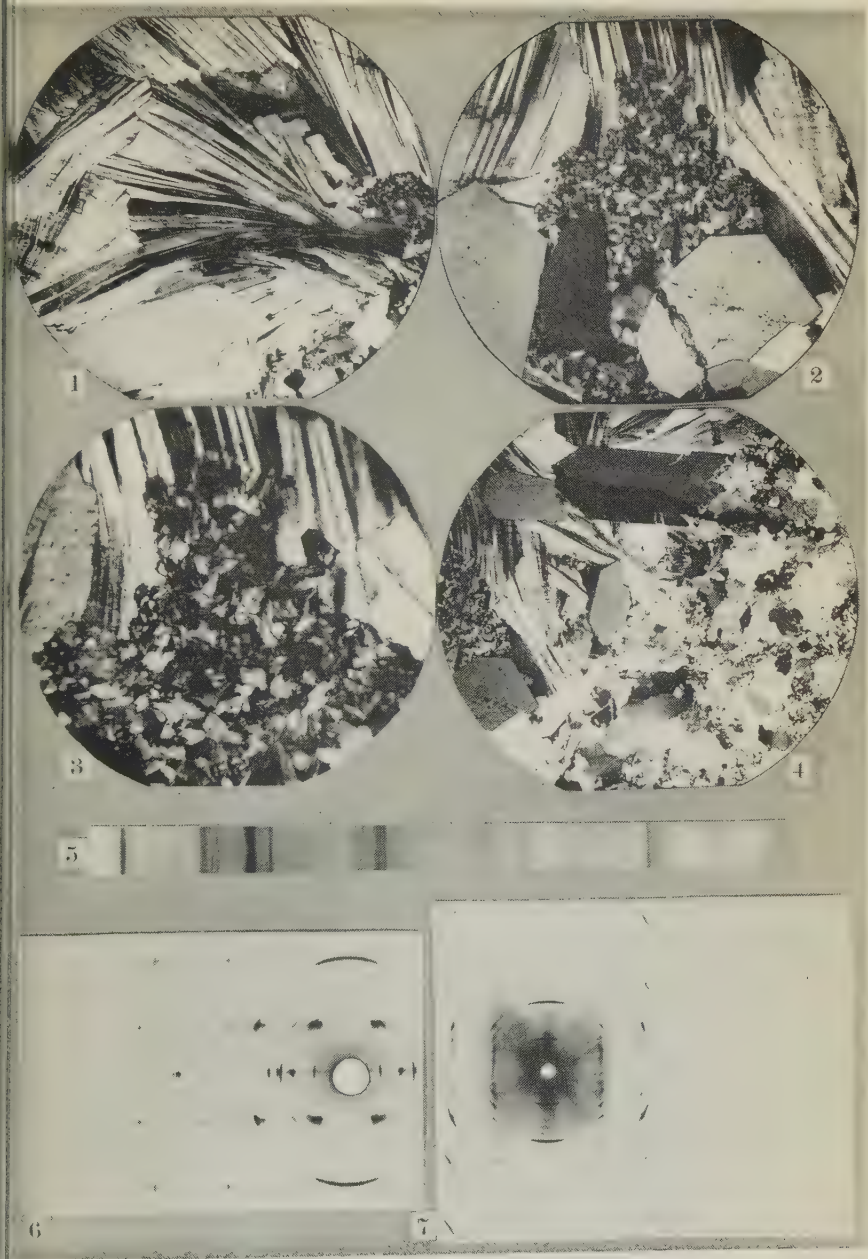
Fig. 3. Kaolinite 'replacing' nacrite. Crossed nicols. × 54.

Fig. 4. Contact between the minerals in the cavity and the surrounding quartzite. Crossed nicols. × 17.

Fig. 5. X-ray powder photograph.

Fig. 6. X-ray rotation photograph about the b-axis (vertical on the page).

Fig. 7. X-ray rotation photograph about the c-axis (horizontal on the page.)



O. VON KNORRING, G. W. BRINDLEY, AND K. HUNTER: PHOTOMICROGRAPHS AND X-RAY PHOTOGRAPHS OF NACRITE FROM FINLAND.

Nacrite from Groby, Leicestershire.

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Department of Mineralogy, British Museum.

[Taken as read June 12, 1952.]

IN the summer of 1951 Mr. R. J. King of Leicester collected from the shatter zone of the main fault in Sheet Hedges Wood quarry, Groby, Leicestershire, specimens of slickensided syenite with quartz veins which contained a creamy white, soapy or powdery material in small cavities in the quartz and on surfaces of movement. The mineral was found from X-ray powder photographs to be the rare clay mineral nacrite. Subsequent searching by Mr. King this year has failed to produce more than a very few grams, mostly on one specimen. The mineral seems to be confined to the region of the main fault and has not been seen in any other part of the quarry.

Microscopically the material is a fine-grained aggregate of irregular and roughly equidimensional crystals mostly in the range 0·001 to 0·01 cm. diameter with an average of about 0·003 cm. Extinction is undulose especially in the larger units. The mean refractive index is about 1·560.

The X-ray powder pattern (table I) of Groby nacrite may be compared with the data given in the preceding paper for nacrite from other localities. Several lines marked 'broad' or 'band' in table III (p. 971) are here resolved into distinct doublets.

Table I. X-Ray powder data for nacrite from Groby, Leicestershire. (Cu-$K\alpha$ radiation; camera diameter 6 cm.).

I.	*d*(Å.)	*I.*	*d*(Å.)	*I.*	*d*(Å.)	*I.*	*d*(Å.)
vs	7·23	m	2·43	vvw	1·772	vvw	1·417
ms	4·38	vvw	2·34	vvw	1·735	w	1·369
m	4·12	vvw	2·29	vw	1·685	vvw	1·340
vvw	3·96	vvw	2·26	vvw	1·660	vvw	1·312
s	3·59	vwb	2·09	vwb	1·619	vw	1·283
vwb	3·44	vw	1·95	vvwb	1·584	mw	1·268
w	3·07	vw	1·93	s	1·489	vwb	1·237
vvw	2·93	vvw	1·897	mw	1·463	vw	1·210
vw	2·59	vvw	1·800	vw	1·435	vw	1·195
w	2·52						

This appears to be the first record of the occurrence in Britain of nacrite as a distinct mineral species.

Nineteenth list of new mineral names.

By L. J. Spencer, C.B.E., M.A., Sc.D., F.R.S.
Formerly Keeper of Minerals in the British Museum.

[Communicated June 12, 1952.]

PREVIOUS lists of this series have been given every three years at the ends of vols. 11–28 (1897–1949) of this Magazine. Lists 1–18 contained 2713 names and in the present list there are 222. Except for a few of the later names, they are all included in Dr. M. H. Hey's useful Index,[1] with page-references to the several lists, so providing a long-wanted general index.[2] References to Mineralogical Abstracts are given in the form [M.A. **11**–].

In the index to the 'new Dana' (7th edition, vol. 1, 1944) there is an entry 'unnamed mineral' with several page references. These have been pounced upon by Gagarin and Cuomo[3] and they have lavishly supplied names where the original authors had wisely refrained. Search of the recent literature revealed other unnamed minerals; and for Argentine minerals they have altered the spelling of names to conform with Spanish pronunciation. In all, they have provided 57 names, which it seems must be listed, if only for convenience of reference.

Only a small (and haphazard) selection has been made of the numerous compound names for artificially produced base-exchange products.

Allargentum. P. Ramdohr, 1950. Die Erzmineralien und ihre Verwachsungen, Berlin, pp. 205, 261, 264; Fortschr. Min., 1950, vol. 28 (for 1949), p. 69 („Allargentum"). Hexagonal ϵ-modification of silver containing antimony (Ag,Sb), Sb 8 15 %, as an exsolution product in dyscrasite from Cobalt, Ontario. Named from ἄλλος, another, and argentum, silver. [M.A. **11**–312.]

Allenite. G. Gagarin and J. R. Cuomo, 1949, loc. cit. p. 13 (allenita). $MgSO_4.5H_2O$ in the chalcanthite group; dehydration product of epsomite

[1] M. H. Hey, An index of mineral species & varieties arranged chemically. With an alphabetical index of accepted mineral names and synonyms. London (British Museum), 1950. [M.A. **11**—117.]

[2] The 1500 names in lists 1–10 are included in one alphabetical arrangement in the General Index (1926) to vols. 11–20 (1895–1925) of this Magazine.

[3] G. Gagarin and J. R. Cuomo, Algunas proposiciones sobre nomenclatura mineralógica. Comunic. Inst. Nac. Invest. Cienc. Nat. (Museo Argentino Cienc. Nat. 'Bernardino Rivadavia'), Cienc. Geol., Buenos Aires, 1949, vol. 1, no. 5, 21 pp. [M.A. **11**–128.] The cumbersome title of this periodical has not been repeated for the 57 names in the following list.

($MgSO_4.7H_2O$) as distinct from hexahydrite ($MgSO_4.6H_2O$, 6th List). Named after Dr. Eugene Thomas Allen (1864-), formerly chemist in the Geophysical Laboratory, Washington, who analysed in 1927 material from 'The Geysers', Sonoma Co., California. Not to be confused with allanite (T. Thomson, 1810). Synonyms, magnesium-chalcanthite, pentahydrite (qq.v.). Allenite is a trade-name for tungsten carbide tools. [M.A. **11**–517.]

Allevardite. S. Caillère and S. Hénin, 1950. Compt. Rend. Acad. Sci. Paris, vol. 230, p. 668; S. Caillère, A. Mathieu-Sicaud, and S. Hénin, Bull. Soc. Franç. Min. Crist., 1950, vol. 73, pp. 141, 193. A paper-like mineral from La Table in Savoie, near Allevard in Isère, previously referred to kaolinite, mica, and palygorskite. Named from the locality. Alternative names suggested are caillérite, déribérite, tablite, and tabulite (qq.v.). [M.A. **5**–521, **8**-225, **10**-43, 371, **11**–127, 190.]

Allophane-evansite, Allophane-chrysocolla. C. S. Ross and P. F. Kerr, 1934. Prof. Paper U.S. Geol. Surv., no. 185–G, p. 147 (allophane-evansite). Mixtures of amorphous minerals. [M.A. **6**-136.] Compare phosphate-allophane, 17th List.

Alpha-cerolite. I. I. Ginzburg and I. A. Rukavinshnikova, 1950. Mém. Soc. Russe Min., vol. 79, p. 33 ((Альфа-керолит). *See* Beta-cerolite. [M.A. **11**–405.]

Aluminium-autunite. C. Frondel, 1951. Amer. Min., vol. 36, p. 671 (aluminum-autunite). Synonym of sabugalite (q.v.). [M.A. **11**–412.]

Alumoantigorite, Alumochrysotile, Alumodeweylite. N. Efremov, 1951. Fortschr. Min., vol. 29–30 (for 1950–51), p. 85 (Alumoantigorit, Alumochrysotil, Alumodeweylith). Serpentine minerals containing Al_2O_3 2·55–6·27 %. Compare Alumino-chrysotile (17th List).

Ammonia-nitre. Dana's Mineralogy, 7 edit., 1951, vol. 2, p. 305 (ammonia niter), Ammonium nitrate (NH_4NO_3, nitrammite of C. U. Shepard, 1857, of doubtful occurrence in a Tennessee cave.

Ammonium-uranospinite. *See* hydrogen-uranospinite.

Anosovite. K. Kh. Tagirov, 1951. A. A. Rusakov and G. S. Zhdanov, Doklady Acad. Sci. USSR, 1951, vol. 77, p. 411 (Аносовит); D. S. Belyankin and V. V. Lapin, ibid., 1951, vol. 80, p. 421. Titanium oxide Ti_3O_5 as black orthorhombic crystals and in blast-furnace slag. Named after the Russian metallurgist P. P. Anosov. [M.A. **11**–415, 536.]

Arsenoestibio. F. Pardillo, 1947. Tratado de mineralogía, translation of 12th edit. of F. Klockmann and P. Ramdohr, Barcelona, p. 315; G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Spanish form of stibarsen (16th List). *See* Wretbladite.

Auricupride. P. Ramdohr, 1950. Fortschr. Min., vol. 28 (for 1949),

p. 69 (Auricuprid). Synonym of cuproauride (15th List). [M.A. **11**–312.]

Aurosirita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 4. Contraction in Spanish form of aurosmirid, aurosmiridium (14th and 17th Lists).

Aurostibite. A. R. Graham and S. Kaiman, 1951. Program & Abstracts, Min. Soc. Amer., Nov. 1951, p. 15; Bull. Geol. Soc. Amer., 1951, vol. 62, p. 1444; Amer. Min., 1952, vol. 37, pp. 292, 461. $AuSb_2$, cubic with pyrite structure, as minute grains in gold ores from Canada. [M.A. **11**–414.]

Bararite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 106. Hexagonal fluosilicate of ammonium $(NH_4)_2SiF_6$, occurring, with cryptohalite (cubic $(NH_4)_2SiF_6$), over a burning coal seam at Barari, Jharia coalfield, India. [M.A. **3**–308, 6–42.]

Barium-autunite. J. Beintema, 1938. Rec. Trav. Chim. Pays-Bas, vol. 57, p. 171 (barium autunite). Artificial base-exchange product of autunite. *See* Calcium-autunite. Synonym of Bariumphosphoruranit, barium-uranite, uranocircite. [M.A. **4**–307, **7**–237, **11**–108.]

Belyankinite. V. I. Gerasimovsky and M. E. Kazakova, 1950. Doklady Acad. Sci. USSR, vol. 71, p. 925 (Белянкинит). $2CaO.12TiO_2.\frac{1}{2}Nb_2O_5.ZrO_2.SiO_2.28H_2O$. Platy yellowish-brown masses, optically biaxial, in nepheline-syenite-pegmatite from Kola peninsula, Russia. Named after Prof. Dmitry Stepanovich Belyankin Дмитрий Степанович Белянкин (1876–). [M.A. **11**–123.]

Belyankite. M. D. Dorfman, 1950. Doklady Akad. Sci. USSR, vol. 75, p. 852 (белянкит). $Ca_3Al_2F_{12}.4H_2O$ as white monoclinic crystals in kaolinized granite from Kazakhstan. Named after Prof. Dmitry Stepanovich Belyankin Дмитрий Степанович Белянкин (1876–). [M.A. **11**–311.]

Beta-cerolite. I. I. Ginzburg and I. A. Rukavishnikova, 1950. Mém. Soc. Russe Min., vol. 79, p. 33 (Бэта-керолит). $MgSiO_3.H_2O$, differing from alpha-cerolite (q.v.) in optical, thermal, and X-ray data. [M.A. **11**–405].

Blakeite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 10 (blakeita). Titano-zirconate of Th, U, Ca, Fe, &c., described as zirkelite from Ceylon by G. S. Blake and G. F. H. Smith (Min. Mag. **16**–309), but differing in chemical composition and also apparently in crystalline form from the original zirkelite from Brazil (Min. Mag. **11**–86, 180). Named after George Stanfield Blake (1876–1940), formerly government geologist in Palestine. Not the blakeite of J. D. Dana, 1850, nor of C. Frondel and F. H. Pough, 1944 (17th List).

Boldyrevite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 8 (boldyrevita). $NaCaMgAl_3F_{14}.4H_2O$ as yellow crusts, optically isotropic, in fumaroles on lava from the Klyuchevsky volcano in Kamchatka, described by S. I. Naboko in 1941 [M.A. **8**–342]. Named after Anatolii Kapitonovich Boldyrev Анатолий Капитонович Болдырев (1883–1946), professor of crystallography and mineralogy in the Mining Institute of Leningrad.

Buergerite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 7 (buergerita). The 15*R* polymorph $Zn_{15}S_{15}$ of wurtzite. Named after Dr. Martin Julian Buerger (1903) of the Massachusetts Institute of Technology, Cambridge, Mass. [M.A. **10**–532, **11**–126, 128.]

Byströmite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 6 (byströmita). Monoclinic magnetic pyrites of Anders Byström, 1945, as distinct from hexagonal pyrrhotine. [M.A. **9**–224.]

—— B. Mason and C. J. Vitaliano, 1950. Progr. & Abstr. Min. Soc. Amer., p. 16; Amer. Min., 1951, vol. 36, p. 320; 1952, vol. 37, p. 53 (bystromite). Magnesium antimonate, $MgSb_2(O,OH)_6$, tetragonal, massive, pale blue-grey, from El Antimonio, Sonora, Mexico. Named after Anders Byström, Swedish mineral chemist, who determined the crystal structure of the artificial compound. [M.A. **11**–188, 516.]

Caillerite. Bull. Soc. Franç. Min. Crist., 1950, vol. 73, p. 147 (caillérite). G. T. Faust and M. Fleischer, Amer. Min., 1952, vol. 37, p. 135 (caillèrite). Alternative name suggested for allevardite (q.v.). Named after Mlle Simonne Caillère, of the Nat. Hist. Mus., Paris.

Calcantite. Italian (and Spanish, calcantita) spelling of chalcanthite.

Calcium-autunite. J. G. Fairchild, 1929. Amer. Min., vol. 14, p. 265 (calcium autunite), p. 269 (calcium-autunite). Artificially prepared autunite in which calcium can be replaced by Na, K, Ba, Mn, Cu, Ni, Co, Mg. Synonym of autunite. *See* Barium-autunite, Lead-autunite, Sodium-autunite. [M.A. **4**–307.]

Calcium-jarosite. D. I. Serdyuchenko, 1951. Doklady Acad. Sci. USSR, vol. 78, p. 347 (кальциевый ярозит), p. 348 (Ca-ярозит). An impure jarosite from Caucasus containing CaO 1·58 %, corresponding to 27·4 % Ca-jarosite $Ca[Fe_3(SO_4)_2(OH)_6]_2$, with K-jarosite, Na-jarosite, and 50·1 % carphosiderite. [M.A. **11**–366.]

Calcomenita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Spanish form of chalcomenite. [M.A. **11**–129.]

Calomelite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 8 (calomelita). Synonym of calomel.

Camermanite. M. E. Denaeyer and D. Ledent, 1950. Bull. Soc. Franç. Min. Crist., vol. 73, p. 483; 1952, vol. 75, p. 231. Hexagonal

form of K_2SiF_6, dimorphous with cubic hieratite, in encrustations of potassium salts at chemical works.

Capillitite. V. Angelelli, 1948. F. Ahlfeld and V. Angelelli, Las especies minerales de la República Argentina, Jujuy, 1948, p. 143 (capillitita; misprint, capillita). E. E. Galloni, Amer. Min., 1950, vol. 35, p. 562 (ferroan zincian rhodochrosite). M. M. Radice, Notas Museo La Plata, 1949, vol. 56, Geol. no. 56, p. 231 (carbonato blanco). (Mn,Zn,Fe) CO_3, containing MnO 29·80, ZnO 14·88, FeO 13·93%. A variety of rhodochrosite from Capillitas, Catamarca. [M.A. **11**–119, 188, 403.]

Carbonate-whitlockite. C. Frondel, 1943. Amer. Min., vol. 28, p. 230; Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 686. Whitlockite ($Ca_3P_2O_8$) containing some CO_2, in phosphate-rock, West Indies.

Chalcocyanite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 578. Anhydrous cupric sulphate $CuSO_4$. To replace the name hydrocyanite (A. Scacchi, 1873), because the pure mineral contains no water (but is then white, not blue). Named from *χαλκός*, copper, and *κύανος*, dark blue.

Chernikite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 10 (chernikita). Tantalo-tungstate of Ti, Ca, Fe, &c. from Kola, analysed in 1927 by G. P. Chernik Г. П. Черник. [Dana, 7th edit. **1**–741.]

Chilkinite. F. Permingeat, Bull. Soc. Franç. Min. Crist., 1951, vol. 74, p. 182. French spelling of shilkinite (16th List).

Chiropterite. O. Abel, 1922. [Höhlenkundliche Vorträge, Heft 7, Wien.] O. Abel and G. Kryle, Die Drachenhöhle bei Mixnitz, Spelaeol. Monogr. Wien, 1931, vol. 7–8, p. 182 (Chiropterit). G. E. Hutchinson, Bull. Amer. Mus. Nat. Hist., 1950, vol. 96, p. 381. Bat guano in caves; named from chiroptera, order of bats. The Times, February 1, 1932 ("Battite").

Chrome-kaolinite. T. Sudo and T. Anzai, 1942. Proc. Imp. Acad. Tokyo, vol. 18, p. 403 (Chrome-kaolinte [*sic*]). Z. Harada, Journ. Fac. Sci. Hokkaido Univ., Ser. 4, 1948, vol. 7, p. 195 (Chrome Koalin [*sic*]), p. 200 (Chrome Kaolin). A green variety of kaolinite containing Cr_2O_3 0·41–1·12 %, occurring with nickel ores, and previously thought to be garnierite, from Urakawa, Sizuoka prefecture, Japan.

Chrome-halloysite. G. S. Gritzaenko and S. V. Grum-Grzhimailo, 1949. Mém. Soc. Russe Min., vol. 78, p. 61 (хромовый галлуазит). A pale blue variety of halloysite containing Cr_2O_3 0·59 %. [M.A. **11**–346, chromium halloysite.]

Clinostrengite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14 (clinostrengita). Monoclinic $Fe'''PO_4.2H_2O$, dimorphous with orthorhombic strengite. Syn. of phosphosiderite and metastrengite (q.v.).

Clinovariscite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14

(clinovariscita). Monoclinic $AlPO_4.2H_2O$, dimorphous with orthorhombic variscite. Synonym of metavariscite (10th List). [M.A. **8** 51.]

Cobalt-cabrerite. H. Meixner, 1951. Neues Jahrb. Min., Monatshefte, 1951, p. 17 (Kobaltcabrerit). Mixed crystals, $(Co,Mg)_3(AsO_4)_2.8H_2O$, with optical data intermediate between those of erythrite and hörnesite. *See* Nickel-cabrerite. [M.A. **11**–312.]

Cobaltocalcite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 175. To replace the generally accepted name sphaerocobaltite (A. Weisbach, 1877) for rhombohedral $CoCO_3$. Not the cobaltocalcite of F. Millosevich, 1910 (5th List), a red cobaltiferous variety of calcite.

Collusite. K. Kinosita, 1944. [Journ. Japanese Assoc. Min. Petr. Econ. Geol., vol. 31, p. 11]; Z. Harada, Journ. Fac. Sci. Hokkaido Univ., Ser. 4, 1948, vol. 7, p. 151. A variety of tetrahedrite containing Sn 3·21 % from Japan. Error for colusite (13th List).

Colombianite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 4 (colombianita). Gold-amalgam (Hg 57·4 %) from Colombia, South America, analysed by H. Schneider in 1848.

Comstockite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 13 (comstockita). $(Mg,Cu,Zn)SO_4.5H_2O$, containing ZnO 5·60, MgO 9·40, CuO 9·00, H_2O 39·07 %, from the Comstock lode, Nevada. Syn. of zinc-magnesia-chalcanthite (C. Milton and W. D. Johnston, Econ. Geol., 1938, vol. 33, p. 761). (15th List.)

Cupro-mangano-aphthitalite. G. Bianchini, 1937. Rend. Accad. Sci. Fis. Mat. Napoli, ser. 4, vol. 7, p. 43 (aftitalite cupro-manganesifera). O. M. Shubnikova, Trans. Inst. Geol. Sci. USSR, 1940, no. 31, p. 53 (купро-мангано-афтиталит, cupro-mangano-aphthitalite). Aphthitalite from Vesuvius containing Cu 1·13, Mn 0·61 %. [M.A. **9** 144, 125.]

Cupromontmorillonite. M. Fleischer, 1951. Amer. Min., vol. 36, p. 793, abstract of the original paper, interpreting the Russian name medmontite (q.v.).

Curzite. S. J. Thugutt, 1949. Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 18 (for 1948), p. 5 (curzite), p. 14 (courzite), p. 35 (kurcyt). Another spelling of kurtzite (18th List).

Dalyite. R. Van Tassel, 1952. Min. Mag., vol. 29, p. 850. Potassium zirconium silicate, $K_2ZrSi_6O_{15}$, triclinic, from Ascension Island, Atlantic. Named after Reginald Aldworth Daly (1871–), emeritus professor of geology, Harvard University.

Davisonite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 939. Correction of the name 'dennisonite' as given by E. S. Larsen and E. V. Shannon, 1930 (12th List), after John Mason Davison (1840–1915) of the University of Rochester, New York. [Min. Mag. **11**–226; M.A. **4**–343.]

Déribérite. E. Lemoine, 1950, Bull. Soc. Franç. Min. Crist., vol. 73, p. 146. Alternative name suggested for allevardite (q.v.). Named after Maurice Déribéré of Paris, who gave a description of the mineral [M.A. **10**–43].

Descloizeauxita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Variant of descloizite (A. Damour, 1854), named after Alfred Louis Olivier Legrand Des Cloizeaux (1817–1897).

Eckrite. J. Ravier, 1951. Bull. Soc. Franç. Min. Crist., vol. 74, p. 10. A variety of soda-amphibole near arfvedsonite in its optical characters but near glaucophane in chemical composition. Named from the locality, Eqe (pronounced éckré), west Greenland. [M.A. **11**–365.]

Efremovite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14 (efremovita). Calcium ferri-phosphate кальциевый ферри-фосфат, $2CaO.3Fe_2O_3.2P_2O_5.10H_2O+16aq.$, of N. E. Efremov Н. Е. Ефремов, 1936, from Taman peninsula, Kuban. [M.A. **6**–439.]

Eisen-Åkermannit. *See* Iron-åkermanite.

Episcolecite. S. J. Thugutt, 1949. Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 18 (for 1948), p. 15 (episcolecite), p. 35 (metaskolecyt). A suggested dimorphous form of scolecite as a derivative of sodalite. Compare metascolecite (1st List; *for* F. Rinne, 1894 *read* F. Rinne, 1890), epinatrolite and metanatrolite (6th List).

Epithomsonite. S. J. Thugutt, 1949, Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 18 (for 1948), p. 5 (epithomsonite), p. 17 (metameric thomsonite), p. 35 (metatomsonit). A suggested dimorphous form of thomsonite as a derivative of sodalite; identified with the metathomsonite (q.v.) of M. H. Hey (1932). Compare epinatrolite and metanatrolite (6th List). [M.A. **11**–291.]

Eskebornite. P. Ramdohr, 1948 (MS.). H. Strunz Min. Tab., 2nd edit., 1949, p. 78 (Eskebornit). P. Ramdohr, Fortschr. Min., 1950, vol. 28 (for 1949), p. 70; Die Erzmineralien und ihre Verwachsungen, Berlin, 1950, p. 418. At first described as hexagonal iron selenide FeS [cf. achavalite, 18th List]. Later as cubic and containing also copper. Named from the locality, Eskeborn level, Tilkerode, Harz. [No relation to bornite.] [M.A. **11**–118, 312.]

Esporogelita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 12. Spanish form of sporogelite (6th List).

Estibioluzonita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 16. Spanish form of stibioluzonite.

Evaporate, Evaporite. A. W. Grabau, 1920. Principles of salt deposition, New York & London, pp. 14, 79 (evaporates), p. 15 (evaporate). C. P. Berkey, Bull. Geol. Soc. China, 1922, vol. 1, p. 24 (evaporate

changed to evaporite); reprinted in New York State Mus. Bull., 1924, no. 251, p. 116. Salts deposited from solution by evaporation, as distinct from precipitates deposited by reaction. [Cf. distillate, crystallate, precipitate.] [M.A. **1** 322, **2**–307, **10**-184, 567; Min. Mag. **28**–621.]

Ferri-alluaudite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 674. Fe-alluaudite of P. Quensel, 1937 [M.A. **6**–485].

Ferristilpnomelane. A. N. Winchell, 1951. Optical mineralogy, pt. 2, 4th edit., p. 390. Oxidized ferrostilpnomelane (15th List); synonym of chalcodite.

Ferrite. K. Kristoffersen, 1950. K. Norske Vid. Selsk. Skrifter, for 1947, no. 4, p. 14 (gronnbrunt naleformig mineral (ferritt), dikalsiumferritt $2CaO.Fe_2O_3$, tetrakalsiumaluminatferritt $4CaO.Al_2O_3.Fe_2O_3$), p. 308 (Ferrite, dicalcium alumoferrite). Used alternatively as a mineral or chemical name for green to brown needles, Ca_2AlFeO_5 to $Ca_2Fe_2O_5$, present in basic slags. Those of the composition Ca_2AlFeO_5 are identical with brownmillerite (16th List). For previous uses of the name ferrite see 6th List. [M.A. **11**–191.]

Ferritremolite. A. N. Winchell, 1949. Amer. Min., vol. 34, p. 224; Optical mineralogy, pt. 2, 4th edit., 1951, p. 437. Hypothetical molecule $Ca_2Fe''_3Fe'''_2O_2Si_8O_{22}$, in oxyhornblende. Compare ferrotremolite (13th List).

Ferritschermakite. A. N. Winchell, 1949. Amer. Min., vol. 34, p. 224; Optical mineralogy, pt. 2, 4th edit., 1951, p. 437. Hypothetical molecule $Ca_2Fe''(Al,Fe''')_4O_2Si_6Al_2O_{22}$, in oxyhornblende. Compare ferrotschermakite (17th List).

Ferrocarpholite. W. P. de Roever, 1951. Amer. Min., vol. 36, p. 736. $H_4FeAl_2Si_2O_{10}$, orthorhombic, analogous to carpholite with Fe in place of Mn. [M.A. **11**–413.]

Ferropericlase. C. E. Tilley, 1951. Min. Mag., vol. 29, p. 629. Iron-bearing variety of periclase, (Mg,Fe)O. Compare magnesiowüstite (14th List).

Ferrowollastonite. S. O. Agrell, 1950. Amer. Min., vol. 35, p. 1080. Synonym of iron-wollastonite (14th List).

Fleischerite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 7 (fleischerita). The $6H$ polymorph Zn_6S_6 of wurtzite. Named after Dr. Michael Fleischer (1908–) of the United States Geological Survey. [M.A. **10**-532, **11**–126, 128.]

Fluor-mica. J. E. Comeforo, R. A. Hatch, and W. Eitel, 1950. Progr. & Abstr. Min. Soc. Amer., p. 9 (fluor-micas); Amer. Min., 1951, vol. 36, p. 313. R. A. Hatch, W. Eitel, and R. A. Humphrey, ibid., 1950,

p. 13; ibid., 1951, p. 317 (fluorine-micas, F-micas, F-phlogopite, F-muscovite, F-talc, F-pyrophyllite). Cf. Fluor-phlogopite (14th List).

Fluor-richterite. J. E. Comeforo, R. A. Hatch, and W. Eitel, 1950. Progr. & Abstr. Min. Soc. Amer., p. 8 (fluo-richterite); Amer. Min., 1951, vol. 36, p. 312. Artificial fluorine-amphiboles (p. 312), fluoramphibole, fluor-amphiboles (p. 313) containing F in place of OH. Compare fluor-amphibole (14th List) and fluor-tremolite (15th List).

Fojasite, fożasyt. S. J. Thugutt, 1949. Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 18 (for 1948), p. 26 (fojasite), p. 35 (fożasyt). Polish spellings of faujasite, named by A. Damour in 1842 after Barthélemy Faujas de Saint-Fond (1741–1819).

Fosfo-escorodita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14. Spanish form of phospho-scorodite (q.v.).

Fosfosiderita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14. Spanish form of phosphosiderite. [M.A. **11**–129.]

Fringelite. M. Blumer, 1951. Mikrochem., Mikrochim. Acta, Wien, vol. 36–37, p. 1052 (Fringelit). A red hydrocarbon dye as minute birefringent crystals in the calcite of fossil crinoids in Jurassic limestone from Fringeli, Bern. Named from the locality. [M.A. **11**–519.]

Frondelite. M. L. Lindberg, 1949. Amer. Min., vol. 34, p. 541. A dufrenite-like mineral, $(Mn'',Fe'')Fe_4'''(PO_4)_3(OH)_5$, isomorphous with rockbridgeite (q.v.) with Mn″ in place of Fe″, orthorhombic, as radially fibrous masses from Brazil. Named after Prof. Clifford Frondel (1907–) of Harvard University. [M.A. **11**–8.]

Gallium-albite, gallium-anorthite, gallium-orthoclase, &c. J. R. Goldsmith, 1950. Journ. Geol. Chicago, vol. 58, p. 522 (gallium albite, germanium albite, gallium-germanium albite), p. 524 (gallium orthoclase, germanium orthoclase, gallium-germanium orthoclase), p. 527 (gallium anorthite, germanium anorthite, gallium-germanium anorthite). Artificial felspars with gallium in place of aluminium and germanium in place of silicon, $NaGaSi_3O_8$, $NaAlGe_3O_8$, $NaGaGe_3O_8$, &c. [M.A. **11**–326.]

Garibaldite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5 (garibaldita). Monoclinic β-sulphur = Sulfurite of J. Fröbel, 1845, from the fumaroles of Italian volcanoes. Named after Giuseppe Garibaldi (1807–1882), liberator of Italy.

Genaruttite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 9 (genaruttita). Cadmium oxide, CdO, cubic (3rd List, p. 380) from Genarutta mine, Monteponi, Sardinia. Syn. of monteponite (18th List).

Germanium-albite, &c. *See* Gallium-albite.

Glimmerton. K. Endell, U. Hofmann, and E. Maegdefrau. 1935. (Zement. Berlin-Charlottenburg vol. 24, p. 627. A micaceous clay. Synonym of illite (15th list).

Gregorite. J. A. Page. 1818. Trans. Roy. Geol. soc. Cornwall, vol. 1, p. 229 (Oxygenite (Mesotenzone)). Synonym of ilmenite. Named after William Gregor (1761–1817), who discovered titanium. Not the gregorite of G. J. Adam, 1868, synonym of agnesite, also from Cornwall and named after William Gregor.

Guimarãesite. G. Gagarin and J. R. Cosme. 1949. loc. cit., p. 11 (guimarãesite). Tantalo-niobate of Ti, U, Fe, &c., as orthorhombic crystals from Divino de Uba, Braz., resembling ampangabeite but containing more Ti and less U. Named after the Brazilian mineralogist Djalma Guimarães, who described it in 1929 [M.A. 3–113. Dana, 7th edit., 1944, vol. 1, p. 897].

Gunnbjarnite. O. B. Boggild. 1951. Meddel. Grønland, vol. 142, no. 8, p. 3. $(Fe^{"}Al)_2O_3.3(Mg,Ca,Fe^{"})O.2Sb_2O_5.3H_2O$, orthorhombic, as black micaceous plates in basalt, east Greenland. Named after Gunnbjørn Ulfsson, discoverer of Greenland about A.D. 900 [M.A. 11–517].

Hanléite. L. L. Fermor. 1932. Geol. Mag. Hertford, vol. 69, p. 145 (hanleite). The garnet molecule $Mg_3(Cr_2(SiO_4)_3$, represented by a mineral resembling uvarovite, described by F. R. Mallet in 1880, in chromite from near the Hanle monastery, Kashmir. Named from the locality. [M.A. 11–518.]

Hondurasite. G. Gagarin and J. R. Cosme. 1949. loc. cit., p. 9 (hondurasite). To replace the name nagyágite of E. S. Dana and H. L. Wells, 1890, which has been given in Spanish as telururanio (q.v.). Named from the locality, Honduras.

Hoppingite. G. Gagarin and J. R. Cosme. 1949. loc. cit., p. 8 (hoppingite). Mercuric iodide as minute scarlet cubes from Broken Hill, New South Wales. Described as distinct from coccinite, by A. J. Moses, 1901, from material submitted by Roy Hopping, mineral dealer of New York.

Hühnerkobelite. M. L. Lundberg. 1950. Amer. Min., vol. 35, pp. 59, 75. Partly oxidized material with the composition $(Na_2Ca)O.2(Fe,Mn)O.P_2O_5$ from Hühnerkobel, Bavaria, and Norra, Sweden, previously referred to arrojadite, but differing from this in the X-ray pattern. Named from the locality. [M.A. 11–126.]

Hummerite. A. D. Weeks, E. A. Cisney, and A. M. Sherwood. 1950. Progr. & Abstr. Min. Soc. Amer., p. 22. Hydrous magnesium vanadate, structure unique in appearance to petalite. Named from the locality, Hummer mine, Paradox valley, Montrose Co., Colorado. [M.A. 11–189.]

Hurlbutite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 7 (hurlbutita). The 4*H* polymorph Zn_4S_4 of wurtzite. Named after Dr. Cornelius Searle Hurlbut, Jr. (1906–) of Harvard University. [M.A. **11**–126, 128, **10**–532.]

—— M. E. Mrose, 1951, Program & Abstracts, Min. Soc. Amer., Nov. 1951, p. 19 (Hurlbutite); Bull. Geol. Soc. Amer., 1951, vol. 62, p. 1464; Amer. Min., 1952, vol. 37, p. 296. Calcium beryllium phosphate, $CaBe_2(PO_4)_2$, orthorhombic, in pegmatite from Newport, New Hampshire. [M.A. **11**–414.]

Huttonite. A. Pabst, 1950. Nature, London, vol. 166, p. 157; Amer. Min., 1951, vol. 36, p. 60. C. O. Hutton, Bull. Geol. Soc. Amer., July 1950, vol. 61, p. 678 (uranium-free thorite). Monoclinic thorium silicate, $ThSiO_4$, as minute grains in beach-sand from New Zealand. Named after Professor Colin Osborne Hutton, of Stanford University, California. [M.A. **11**–188, 209, 310.]

Hydrocancrinite. J. Wyart and M. Michel-Lévy, 1949. Compt. Rend. Acad. Sci. Paris, vol. 229, p. 131. An artificial hydrothermal product, $NaAlSiO_4.\frac{1}{2}H_2O$, with the same X-ray pattern as cancrinite. Compare lembergite (1st List). [M.A. **11**–93.]

Hydrogen-uranospinite. M. E. Mrose, 1950. Progr. & Abstr. Min. Soc. Amer., p. 18 (hydrogen-uranospinite); Amer. Min., 1951, vol. 36, p. 322. Artificial $H_2(UO_2)_2(AsO_4)_2.8H_2O$, isostructural with metatorbernite-I. Replacements of H_2 by Na_2 and $(NH_4)_2$ yield sodium-uranospinite and ammonium-uranospinite. [M.A. **11**–365.]

Hydrosodalite. J. Wyart and M. Michel-Lévy, 1949. Compt. Rend. Acad. Sci. Paris, vol. 229, p. 131. An artificial hydrothermal product with the same X-ray pattern as sodalite, but with chlorine replaced by water and CO_2. Compare hydroxyl-sodalite (18th List). [M.A. **11**–93.]

Hydroxyl-herderite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 820. The same as hydro-herderite of S. L. Penfield, 1894 (2nd List).

Illite-hydromica. C. Andreatta, 1949. Periodico Min. Roma, vol. 18, p. 11 (serie illiti-idromiche), p. 14 (illidromica). Titles & abstracts, Internat. Geol. Congress, 18th session, London, 1948, p. 126 (illite-idromica). Clay Minerals Bull., 1949, no. 3, p. 98 (illidromica, illite-hydromica). Rend. Soc. Min. Ital., 1950, vol. 6, p. 40. A micaceous mineral intermediate between illite and hydromica. [M.A. **11**–172, 347.]

Iraurita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Spanish form of iridium-gold (O. E. Zvyagintzev, 1934) [M.A. **6**–51], иридистое золото (V. I. Vernadsky, 1908), iridic gold (M. H. Hey, 1950).

Iridioplatinita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5.

Applied to Ir-Pt alloys rich in platinum. Иридистая платина (V. I. Vernadsky, 1908), iridic platinum (M. H. Hey, 1950). *See* Platinoiridita.

Iron-åkermanite. C. Hlawatsch, 1904. Tschermaks Min. Petr. Mitt., vol. 23, p. 422 (Fe-Akermannit), p. 449 (Eisen-Åkermannit). N. L. Bowen, J. F. Schairer, and E. Posnjak, Amer. Journ. Sci., 1933, ser. 5, vol. 26, p. 282 (iron-akermanite). $2CaO.FeO.2SiO_2$, tetragonal, analogous to åkermanite with Fe in place of Mg. Present in slags and in the system CaO–FeO–SiO_2. [M.A. **5**–454.]

Iron-lazulite. L. Katz and W. N. Lipscomb, 1951. Acta Cryst., vol. 4, p. 345 (iron lazulite). Artificial $(Fe'',Fe''')_7(PO_4)_4(OH)_4$, tetragonal. [Not in agreement with the lazulite-scorzalite series, M.A. **11**–244, 426.]

Iron-reddingite. H. H. Woodard, 1951. Amer. Min., vol. 36, p. 881 (Iron reddingite). Synonym of phosphoferrite. [M.A. **11**–492.]

Irosita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Contraction in Spanish form of iridosmine, applied to Os-Ir alloys rich in osmium [M.A. **7**–162.] *See* Osirita.

Isiganeite. Z. Harada, Journ. Fac. Sci. Hokkaido Univ., Ser. 4, 1948, vol. 7, p. 154 (Isigane-isi) from [Journ. Electrochem. Assoc. Japan, 1939, vol. 7]. Variety of psilomelane, new mineral from Isigane mine, Sasaoka, E-Kasugai Co., Aiti prefecture. Japanese isi, ishi = stone, -ite.

Josenite. A. N. Winchell, Optical mineralogy, 1951, pt. 2, 4th edit., p. 133. Variant of josen (10th List).

Jujuite. F. Ahlfeld and V. Angelelli, Las especies minerales de la República Argentina, Jujuy, 1948, p. 132 (jujuita). G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Variant of jujuyite (18th List). Named from prov. Jujuy, Argentina.

Kali-barium-felspar. Z. Harada, 1948. Journ. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 7, p. 159 (Kali-Barium-Feldspar). A collective name to include celsian, hyalophane, and kasolite.

Kellerite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 13 (kellerita). $(Mg,Cu)SO_4.5H_2O$, containing MgO 11·36, CuO 12·46, H_2O 38·31 %, as bluish-white earthy masses apparently pseudomorphous after chalcanthite, from Copaquire, Chile, described by H. F. Keller, Proc. Amer. Phil. Soc., 1908, vol. 47, p. 81.

Kenngottite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 10 (kenngottita). Vitreous amorphous As_2O_3 (arsenolite) mentioned by J. F. L. Hausmann in 1850 and by Johann Gustav Adolph Kenngott (1818–1897) in 1852. Not the kenngottite (synonym of miargyrite) of W. Haidinger, 1857.

Kobeite. J. Takubo, Y. Ukai, and T. Minato, 1950. Journ. Geol. Soc. Japan, vol. 56, p. 509; abstract in Amer. Min., 1951, vol. 36, p. 924.

Titanate, niobate, and tantalate (Yt,Fe,U,&c.)(Ti,Nb,Ta,&c.)$_2$ (O,OH)$_6$, differing from euxenite, &c., in the low content of $(Nb,Ta)_2O_5$ (4·84–5·45 %). Black metamict crystals in pegmatite from Kobe, Kyoto, Japan. Named from the locality. [M.A. **11**–518.]

Kryzhanovskite. A. I. Ginzburg, 1950. Doklady Acad. Sci. USSR, vol. 72, p. 762 (крыжановскит). A monoclinic mineral, $MnFe_2'''(PO_4)_2(OH)_2.H_2O$, of the dufrenite group. Compare frondelite, laubmannite, and rockbridgeite (qq.v.). Named in memory of Professor Vladimir Ilich Kryzhanovsky Владимир Ильич Крыжановский (1881–1947), curator in the Mineralogical Museum of the Russian Academy of Sciences. [M.A. **11**–189.]

Ktenasite. P. Kokkoros, 1950. Tschermaks Min. Petr. Mitt., ser. 3, vol. 1, p. 342 (Ktenasit). Hydrous basic sulphate $3(Cu,Zn)O.SO_3.4H_2O$, as blue-green monoclinic crystals from Lavrion, Greece. Named after Constantine A. Ktenas *Κωνσταντινος Α. Κτενας* (1885–1935), professor of mineralogy and petrology in the University of Athens. [M.A. **11**–125.]

Kyanotrichite. A. N. Winchell, Optical mineralogy, 1933, pt. 2, 3rd edit., p. 116. Variant of cyanotrichite, German Kyanotrichit, but the original German spelling (E. F. Glocker, 1839) was Cyanotrichit.

Latiumite. C. E. Tilley and N. F. M. Henry, 1952. Min. Soc. Notice, no. 78. Monoclinic sulphatic silicate Ca, K, Al, in ejected blocks from Albano, Latium, Italy. Named from the locality.

Laubmannite. C. Frondel, 1949. Amer. Min., vol. 34, p. 514. A dufrenite-like mineral, $(Fe'',Mn,Ca)_3Fe_6'''(PO_4)_4(OH)_{12}$, orthorhombic?, isostructural with andrewsite; from Polk Co., Arkansas. Named after Dr. Heinrich Laubmann of Munich; the 'dufrenite' from Bavaria which he described in 1923 may perhaps belong here. [M.A. **11**–8.]

Lead-alunite. H. Bassett, 1950, Journ. Chem. Soc. London, 1950, p. 1460 (lead alunite). Artificial $Pb[Al_2(OH)_4(H_2O)_2][SO_4]_2$ as mixed crystals with $H_2O[Al_3(OH)_5H_2O][SO_4]_2$, with the alunite X-ray pattern.

Lead-autunite. J. G. Fairchild, 1929. Amer. Min., vol. 14, p. 265 (lead autunite), p. 273 (lead-autunite). *See* Calcium-autunite.

Leonhardtite. W. Berdesinski, 1952. Neues Jahrb. Min., Monatshefte, p. 29 (Leonhardtit). $MgSO_4.4H_2O$, from the hydration of kieserite. Named after Johannes Leonhardt (1893–), professor of mineralogy and petrography in the University of Kiel. Not to be confused with leonhardite of J. R. Blum, 1843. [M.A. **11**–517.]

Litargita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 9. Spanish spelling of lithargite (8th List). Synonym of litharge.

Lombaardite. H. J. Nel, C. A. Strauss, and F. E. Wickman, 1949 Mem. Geol. Surv. South Africa, no. 43, p. 45. Silicate of Al, Ca, Fe a

monoclinic needles, related to pumpellyite and epidote. From Zaaiplaats tin mine, Transvaal. Named after B. V. Lombaard, professor of geology, university of Pretoria. [M.A. **11** 127.]

Magnalumoxide. N. A. Bobkov and Y. V. Kazitzyn, 1951, Mém. Soc. Russe Min., vol. 80, p. 108 (магналюмоксид). A spinel mineral with excess sesquioxides (as in artificial spinel), $5(Mg,Fe)(Al,Fe)_2O_4.4(Al,Fe)_2O_3 = (Mg,Fe)_5(Al,Fe)_{18}O_{32}$. Black octahedral crystals from Aldan, SE. Siberia. [M.A. **11**–365.]

Magnesium-chalcanthite. A. N. Winchell, 1951. Optical mineralogy, pt. 2, 4th edit., p. 160 (Magnesium chalcanthite). $MgSO_4.5H_2O$, triclinic, the artificial analogue of chalcanthite (*see* copper-chalcanthite, 18th List). Synonym of allenite and pentahydrite (qq.v.).

Magnesium-melanterite. T. Wieser, 1950. Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 19 (for 1949), p. 451 (melanteryt magnezowy), p. 470 (magnesium melanterite). A variety of melanterite containing 3–10 % MgO, from Poland. [M.A. **11**–301.]

Magniophilite. A. A. Beus, 1950. Doklady Acad. Sci. USSR, vol. 73, p. 1267 (магниофилит). $(Mn,Fe,Mg)_3(PO_4)_2$ as salmon-pink crystals intergrown with triphylite, in pegmatite from Turkestan. Differs from graftonite in containing Mg and more Mn than Fe. Named from magnesium and *φιλός*, a friend. [M.A. **11**–190.]

Magniotriplite. A. I. Ginzburg, N. A. Kruglova, and V. A. Moleva, 1951. Doklady Acad. Sci. USSR, vol. 77, p. 97 (магниотриплит). Triplite rich in magnesium. Synonym of talc-triplite. [M.A. **11**–311.]

Magny-monothermite. I. D. Sedletzky and P. S. Samodurov, 1949. Mém. Soc. Russe Min., ser. 2, vol. 78, p. 274 (Магний-монотермит). A clay mineral differing from monothermite (15th List) in containing MgO (2·89 %) in place of K_2O. [M.A. **11**–125.]

Mangan-alluaudite. Dana's Mineralogy, 7th edit., vol. 2, 1951, p. 674. Mn-alluaudite of P. Quensel, 1937. [M.A. **6**–485.]

Manganchalcanthite. A. N. Winchell, 1951. Optical mineralogy, 4th edit., part 2, p. 10. Variant of manganese-chalcanthite (9th List), artificial $MnSO_4.5H_2O$, triclinic.

Mangan-fluorapatite. B. Mason, 1941. Geol. För. Förh. Stockholm, vol. 63, p. 280 (mangan-fluorapatite), p. 281 (Mn-fluorapatite). Compare fluormanganapatite (9th List), mangan-hydroxyapatite (16th List).

Mangani-sicklerite. P. Quensel, 1952. Geol. Mag. Hertford, vol. 89, p. 59. Previously referred to as Mn-sicklerite (P. Quensel, 1937, 14th List, p. 609), manganese sicklerite (W. F. Foshag, Amer. Min., 1937,

vol. 22, p. 876), manganese-sicklerite (16th List), and mangan-sicklerite (Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 672).

Mangankoninckite. A. A. Beus, 1950. Doklady Acad. Sci. USSR, vol. 73, p. 1267 (манганконинкит). $(Fe,Mn)PO_4.3H_2O$, a variety of koninckite containing Mn_2O_3 2·72 %, in pegmatite from Turkestan. [M.A. **11**–190.]

Manganleonite. H. Anspach, Zeits. Krist., 1939, vol. 101, p. 39 (Mn-Leonit). A. N. Winchell, Optical mineralogy, pt. 2, 4th edit., 1951, p. 167 (manganleonite). Artificial $K_2Mn(SO_4)_2.4H_2O$, monoclinic, isomorphous with leonite $(K_2Mg(SO_4)_2.4H_2O)$. [M.A. **7**-393.]

Manganostilpnomelane. A. N. Winchell, 1951. Optical mineralogy, pt. 2, 4th edit., p. 390. Alternative name for parsettensite [M.A. **2**–251; Min. Mag. **25**–189].

Marburgite. S. J. Thugutt, 1949. Rocznik Polsk. Tow. Geol. (Ann. Soc. Géol. Pologne), vol. 18 (for 1948), p. 10 (marburgite), p. 35 (marburgit). The calcium-type of phillipsite, as distinct from the sodium-type ('herschelite'). Named from its locality, Marburg, Hesse.

Masicotite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 9 (masicotita). Variant of massicottite (A. D'Achiardi, 1883) and massicotite (A. H. Chester, 1896). Synonym of massicot.

Matteuccite. G. Carobbi and C. Cipriani, 1952. Atti (Rend.) Accad. Naz. Lincei, Cl. Sci. fis. mat. nat., ser. 8, vol. 12, sem. 1, p. 23. Sodium bisulphate, $NaHSO_4.H_2O$, with mercallite ($KHSO_4$, 14th List) in saline stalactites from Vesuvius. Named after Vittorio Matteucci (1862–1909), a former director of the Vesuvian Observatory. [M.A. **11**-517.]

Medamaite. Z. Harada, Journ. Fac. Sci. Hokkaido Univ., Ser. 4, 1948, vol. 7, p. 153 (Medama-isi) from [Journ. Japanese Ceramic Assoc., 1943, vol. 51, p. 381]. A variety of diaspore from Mutuisi, Wake Co., Okayama prefecture. Japanese isi, ishi = stone, -ite.

Medmontite. F. V. Chukhrov and F. Y. Anosov, 1950. Mém. Soc. Russe Min., vol. 79, p. 23 (Медмонтит). A clayey mineral allied to montmorillonite containing CuO 20·96 %, from Kazakhstan. Named from медь (copper) and montmorillonite. *See* Cupromontmorillonite. [M.A. **11**–124.]

Melnikovite-marcasite. H. Rechenberg, 1950. Neues Jahrb. Min. Monatshefte, 1950, p. 141 (Melnikovit-Markasit). Colloform marcasite containing some water and crystallized from a gel. Analogous to melnikovite-pyrite (14th List). [M.A. **11**–353.]

Mendocita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Variant of mendozite. Named after the province of Mendoza, but in Spanish *z* before *e* or *i* is pronounced as *c*. [M.A. **11**–129.]

Metabasaluminite. F. A. Bannister, 1950. Min. Mag., vol. 29, p. 9. $Al_4SO_4(OH)_{10} = 2Al_2O_3.SO_3.5H_2O$, produced by heating hydrobasaluminite (18th List) at 150° C.

Meta-saléeite. M. E. Mrose, 1950. Amer. Min., vol. 35, p. 529 (meta-saléeite). Further alteration of name, saléite (13th List) and saléeite (15th List), for the Katanga mineral $Mg(UO_2)_2(PO_4)_2.8H_2O$ corresponding to meta-autunite, the name saléeite being transferred to the fully hydrated mineral with $10H_2O$. [M.A. **11**–230.]

Metasanidine. C. Oftedahl, 1949. Skrifter Norske Vidensk.-Akad. Oslo, I. Mat.-Naturv. Kl., for 1948, no. 3, p. 58 (meta-sanidine), p. 68 (metasanidine). An alkali-felspar showing partial exsolution of sanidine to cryptoperthite. [M.A. **11**–11.]

Metastrengite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 769. Monoclinic $FePO_4.2H_2O$ dimorphous with orthorhombic strengite; named to correspond with metavariscite and variscite $AlPO_4.2H_2O$. Synonym of phosphosiderite (Bruhns and Busz, 1890) and clinostrengite (q.v.).

Metathomsonite. M. H. Hey, 1932. Min. Mag., vol. 23, pp. 93–97, 118, 120. Partially dehydrated thomsonite showing a change in phase; probably a high-temperature form identical with gonnardite. *See* Epithomsonite.

Meta-uranopilite. C. Frondel, 1951. Dana's Mineralogy, 7th edit., vol. 2, p. 582. Partially dehydrated uranopilite, β-uranopilite of R. Nováček, 1935 [M.A. **6**–148].

Metazeolites. R. Brauns, 1892. Neues Jahrb. Min., vol. ii, p. 240 (Metazeolithe), in abstract of F. Rinne, 1890, though not given in the original paper. The names metadesmine (1st List), metascolecite (1st List), metanatrolite (6th List), metaepistilbite, were given by F. Rinne, Sitz.-ber. Akad. Wiss. Berlin, 1890, pp. 1203–4, for partially dehydrated zeolites showing changes in optical properties and in some cases of crystal system.

Metazeunerite. A. E. Fersman and O. M. Shubnikova. Geochemist's and mineralogist's companion, 1937, p. 173 (Метацейнерит), $Cu(UO_2)_2(AsO_4)_2.8H_2O$; the same formula is given (p. 306) for zeunerite. J. W. Frondel, Amer. Min., 1951, vol. 36, p. 255 (meta-zeunerite); artificial zeunerite contains 5–16H_2O, and to be consistent with meta-autunite (4th List) and meta-torbernite (7th List) the natural mineral with $8H_2O$ might be called meta-zeunerite. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 993 (metazeunerite). [M.A. **11**–323, 432.]

Miltonite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 13 (miltonita). Calcium sulphate hemihydrate, $CaSO_4.\frac{1}{2}H_2O$, obtained in the

preparation of thin sections of gypsum. [M.A. **8**-280.] Named after Dr. Charles Milton (1896–) of the United States Geological Survey. Found as a natural mineral in deserts in Central Asia, V. I. Popov and A. L. Vorobiev, 1949 [M.A. **11**–366]. Compare bassanite, 6th List.

Miserite. W. T. Schaller, 1950. Amer. Min., vol. 35, p. 911. $KCa_4Si_5O_{13}(OH)_3$, a pink, fibrous (orthorhombic?) alteration product of wollastonite in metamorphosed shale from Arkansas. Previously described as natroxonotlite (J. F. Williams, 1891). Named after Dr. Hugh Dinsmore Miser (1884–) of the United States Geological Survey. [M.A. **11**–187.]

Molibdomenita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Variant of molybdomenite.

Montesite. R. Herzenberg, 1949. Publ. Techn. Inst. Boliviano Ingen. Minas y Geol., Minería Boliviana, no. 45 (montesita). Lead sulphostannite, $PbSn_4S_5$, between teallite ($PbSnS_2$) and herzenbergite (SnS) in composition, and similar to them in appearance. From Bolivia. Named after the late Ismael Montes, founder of the School of Mines at Oruro. [M.A. **11**–10.]

Montroseite. A. D. Weeks, E. A. Cisney, and A. M. Sherwood, 1950. Progr. & Abstr. Min. Soc. Amer., p. 22. $2FeO.V_2O_3.7V_2O_4.4H_2O$, as black orthorhombic blades, from Paradox valley, Montrose Co., Colorado. Named from the locality. [M.A. **11**–189.]

Natro-autunite. A. E. Fersman and O. M. Shubnikova, 1937. Geochemist's and mineralogist's companion, Moscow, p. 177 (Натро(вый) отунит). Variant of sodium-autunite (q.v.).

Natro-melilite. O. M. Shubnikova and D. V. Yuferov, 1934. New minerals 1922 32, Leningrad, Moscow, 1934, p. 71 (натро-мелилит). Synonym of soda-melilite (12th List).

Neogastunite. H. Haberlandt and A. Schiener, Tschermaks Min. Petr. Mitt., 1951, ser. 3, vol. 2, pp. 311, 315 (Neogastunit). Presumably a local name for a uranium mineral, later identified as schröckingerite, from the hot springs at Bad Gastein, Salzburg. [M.A. **11**-433.]

Nickel-cabrerite. H. Meixner, 1951. Neues Jahrb. Min., Monatshefte, 1951, p. 19 (Nickelcabrerit). Synonym of cabrerite, $(Ni,Mg)_3(AsO_4)_2.8H_2O$. *See* Cobalt-cabrerite. [M.A. **11**–312.]

Nickel-magnetite. C. Doelter, 1926. Mineralchemie, vol. 3, pt. 2, p. 666 (Nickelmagnetit). Synonym of trevorite $NiFe_2O_4$ (10th List).

Nogizawalite. T. Kawai, 1949. Journ. Chem. Soc. Japan, Pure Chem. Sect., vol. 70, p. 268. Silicate and phosphate of rare-earths, Zr, Al, Fe, Mg, Ca, tetragonal. Named from the locality, Nogizawa village, Ishikawa district, Japan. [Perhaps a mixture of zircon, xenotime, &c.

Compare oyamalite, 11th List, and yamagutilite, 14th List.] [M.A. **11**–311.]

Nováčekite C. Frondel, 1951. Amer. Min., vol. 36, p. 680 (Novacekite). $Mg(UO_2)_2(AsO_4)_2.9H_2O$, pseudo-tetragonal, isomorphous with saléeite, the corresponding phosphate. From Schneeberg, Saxony. Named after Radim Nováček (1905–42), Czech mineralogist. [M.A. **11**–413.]

Ooguanolite. A. A. Hayes, 1855. Proc. Boston Soc. Nat. Hist., vol. 5, p. 167 (Oöguanolite). G. E. Hutchinson, Bull. Amer. Mus. Nat. Hist., 1950, vol. 96, p. 94 (ooguanolite). Sulphate of potassium and ammonium, $K_2SO_4.(NH_4)_2SO_4$, in a fossilized egg from guano deposits on an island off the coast of Peru. Named from ὠόν, egg, and guano. Compare taylorite ($5K_2SO_4.(NH_4)_2SO_4$) and guanapite. [M.A. **11**–245, 302, 551.]

Osirita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Contraction in Spanish form of osmiridium, applied to Os-Ir alloys rich in iridium. *See* Irosita. [M.A. **7**–162.]

Oxychildrenite. A. I. Ginzburg and N. V. Voronkova, 1950. Doklady Acad. Sci. USSR, vol. 71, p. 145 (оксичильдренит). An oxidized form of childrenite with (Fe,Mn)O changed to $(Fe,Mn)_2O_3$, from Kalbin Mts., Kazakhstan. [M.A. **11**–124.]

Paracancrinite. J. Wyart and M. Michel-Lévy, 1949. Compt. Rend. Acad. Sci. Paris, vol. 229, p. 133. An artificial hydrothermal product with the same X-ray pattern as cancrinite, but containing no calcium. [M.A. **11**–93.]

Pellouxite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 9 (pellouxita). Lime, calcium oxide, CaO, reported from Vesuvius (calce, A. Scacchi, 1883). Named after the Italian mineralogist Alberto Pelloux (1868–1948).

Pentahydrite. C. Frondel, 1951. Dana's Mineralogy, 7th edit., vol. 2, p. 492. Magnesium sulphate pentahydrate, $MgSO_4.5H_2O$, triclinic; artificial, but occurring naturally in mixed crystals (*see* comstockite, kellerite). Named analogously to hexahydrite ($MgSO_4.6H_2O$). The same as allenite and magnesium-chalcanthite (qq.v.).

Perrierite. S. Bonatti and G. Gottardi, 1950. Atti (Rend.) Accad. Naz. Lincei, Cl. Sci. fis. mat. nat., ser. 8, vol. 9, sem. 2, p. 361. Titanosilicate of Yt, Ce, with some Th, Fe, Ca, P_2O_5 (near chevkinite); monoclinic (orthite habit). Found in beach-sand at Nettuno, Roma. Named in memory of the Italian mineralogist Carlo Perrier (1886–1948). [M.A. **11**–310.]

Phosphoscorodite. T. N. Shadlun and Y. S. Nesterova, 1947. Mém. Soc. Russe Min., vol. 66, p. 212 (Фосфоскородит). A white

powdery, optically biaxial mineral midway in composition between scorodite ($FeAsO_4.2H_2O$) and strengite ($FePO_4.2H_2O$). [M.A. **11**–11.]

Pigeonite-augite. E. Tröger, 1951. Neues Jahrb. Min., Monatshefte, 1951, pp. 136, 137 (Pigeonitaugit). A clinopyroxene intermediate between pigeonite and augite. [M.A. **11**–390.]

Platinoiridita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Variant of platiniridium, applied to Ir-Pt alloys rich in iridium. *See* Iridioplatinita.

Porpecita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 4. Spanish pronunciation of porpezite. *See* Mendocita.

Potash-bentonite. P. F. Kerr and P. K. Hamilton, Glossary of clay mineral names, New York, 1949, p. 52 (potash bentonite). Syn. of meta-bentonite (C. S. Ross, 1928, 14th List), metabentonite (J. G. Kay, Journ. Geol. Chicago, 1931, vol. 39, p. 361). Compare potash-montmorillonite (14th List).

Pozzuolite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 7 (pozzuolita). Solfuro arsenicale (Arsenschwefel), $As_2S_3.H_2O$, of E. Monaco 1903, from the solfatara of Pozzuoli, Italy. Not to be confused with pozzolana, pozzuolana, a volcanic tuff used for the manufacture of Roman cement.

Priderite. K. Norrish, 1951. Min. Mag., vol. 29, p. 496. $(K,Ba)_{1\cdot3}(Ti,Fe''')_8O_{16}$, minute red tetragonal crystals, previously mistaken for rutile in leucite-rocks from Kimberley, Western Australia. Related structurally to cryptomelane. Synthetic K-priderite and Ba-priderite (p. 500). Named after Rex Tregilgas Prider, professor of geology in the University of Western Australia.

Promullite. J. E. Comeforo, R. B. Fischer, and W. F. Bradley, 1948. Journ. Amer. Ceramic Soc., vol. 31, p. 259 (pro-mullite). An amorphous stage in the dehydration of kaolin, yielding mullite at a higher temperature. Synonym of metakaolin (10th List). Compare prokaolin (16th List) and promontmorillonite (15th List). [M.A. **11**–452.]

Reitingerite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 11 (reitingerita). Zirconium oxide, ZrO_2, as nodular radially fibrous masses from Brazil, supposed by E. Hussak and J. Reitinger to be dimorphous with baddeleyite, but later shown to be identical. [Min. Mag. **13**–398, **21**–171.]. Named after J. Reitinger of Munich.

Robinsonite. L. C. Berry, J. J. Fahey, and E. H. Bailey, 1951. Program & Abstracts, Min. Soc. Amer., Nov. 1951, p. 8; Bull. Geol. Soc. Amer., 1951, vol. 62, p. 1423; Amer. Min., 1952, vol. 37, pp. 285, 438.

Still another lead sulphantimonite, $7PbS.6Sb_2S_3$, triclinic, from Nevada, and as artificial crystals. Named after Dr. S. C. Robinson, of the Geological Survey of Canada. [M.A. **10** 457–8 ('mineral X'), **11** 414.]

Rockbridgeite. C. Frondel, 1949. Amer. Min., vol. 34, p. 513. Dana's Mineralogy, 7th edit., 1951, vol. 2, p. 867. A dufrenite-like mineral, $(Fe'', Mn'')Fe'''_4(PO_4)_3(OH)_5$, orthorhombic, isomorphous with frondelite (q.v.). Named from one of the localities, Rockbridge County, Virginia. [M.A. **11**–7, 187.]

Rodita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 4. Spanish spelling of rhodite. Not the rodite of A. Brezina, 1885, applied to the Roda (Spain) meteorite and a class of meteorites.

Rubiesite. C. Doelter, 1926. Mineralchemie, vol. 4, pt. 1, p. 838 (Rúbiesit). A mineral described in 1920 by S. Piña de Rúbies and evidently regarded by him as a mixture of sulphide, selenide, and telluride of bismuth and antimony. Doelter's only information was from [M.A. **1**–201].

Rumongite. S. Bracewell, 1950. Rep. Geol. Surv. British Guiana, for 1949, pp. 38, 40 ("Rumongite"). Provisional name for a mineral afterwards identified as ilmenorutile, from the Rumong-Rumong river, British Guiana. [M.A. **11**–251.]

Rutosirita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5. Contraction in Spanish form of ruthenosmiridium (15th List).

Sabugalite. C. Frondel, 1951. Amer. Min., vol. 36, p. 671. $HAl(UO_2)(PO_4)_2.16H_2O$, pseudo-tetragonal, isostructural with fully hydrated autunite. Crusts of minute platy yellow crystals in pegmatite. Named from the locality, Sabugal, Beira, Portugal. Syn. aluminium-autunite, aluminum-autunite (q.v.). [M.A. **11**–412.]

Sanderite. W. Berdesinski, 1952. Neues Jahrb. Min., Monatshefte, p. 28 (Sanderit). $MgSO_4.2H_2O$, from the hydration of kieserite. Named after Bruno (Hermann Max) Sander (1884–), professor of mineralogy and petrography in the Univerity of Innsbruck. [M.A. **11**–517.]

Scholzite. H. Strunz, 1949. Min. Tab., 2nd edit., p. 164 (Scholzit); Fortschr. Min., 1950, vol. 27 for 1948, p. 31. $Ca_2Zn(OH)_2(PO_4)_2.H_2O$, as colourless monoclinic crystals with blende and triplite in pegmatite from Hagendorf, Bavaria. Named after Dr. Adolf Scholz of Regensburg. [M.A. **11**–189.]

Shandite. P. Ramdohr, 1950. Die Erzmineralien und ihre Verwachsungen, Berlin, p. 820 (Shandit, in locality index only); Sitz.-ber. Akad. Wiss. Berlin, 1950, no. 6 (for 1949); Fortschr. Min. 1950, vol. 28 (for 1949), p. 70. M. A. Peacock and J. McArthur, Amer. Min., 1950, vol. 35, p. 425. Rhombohedral $Ni_3Pb_2S_2$ with X-ray pattern distinct

from parkerite and from the artificial β-phase in the system $Ni_3Bi_2S_2$–$Ni_3Pb_2S_2$. From Trial Harbour, Tasmania. Named after Professor Samuel James Shand (1882–), Scottish petrologist. [M.A. **11**-186, 187, 312, 466.]

Siderogel. H. Strunz, 1941. Min. Tab., p. 111 (Siderogel). Colloidal FeO(OH), in bog-iron-ore.

Silfbergite. Author?, date?. Zeits. Krist., 1924, vol. 60, p. 337 (abstracts, no ref.); Dana's Mineralogy, 7th edit., 1944, vol. 1, p. 702. Presumably the 'Mangan-Magnetit' (MnO 3·80 %) from Vester Silfberg, Sweden, analysed by M. Weibull, 1886. Not the silfbergite of M. Weibull, 1883.

Sinhalite. G. F. Claringbull and M. H. Hey, 1952. Min. Mag., vol. 29, p. 841. Borate $MgAlBO_4$, orthorhombic. Hitherto mistaken for brown gem olivine. Named from Sinhala, the Sanskrit name for Ceylon.

Sodium-autunite. J. G. Fairchild, 1929. Amer. Min., vol. 14, p. 265 (sodium autunite), p. 269 (sodium-autunite). *See* Calcium-autunite, natro-autunite.

Sodium-bentonite. J. W. Jordan, 1949. Min. Mag., vol. 28, p. 598. A highly swelling clay from Wyoming.

Sodium-uranospinite. *See* Hydrogen-uranospinite.

Sollyite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 7 (sollyita). A fibrous lead sulpharsenite, $Pb_3As_4S_9$, from Binn, Switzerland, near to rathite in composition, but with interfacial angles near to dufrenoysite. Described (Min. Mag., 1919, **18**–360) by, and now named after, Richard Harrison Solly (1851–1925) of Cambridge.

Stibiobismutotantalite. M. C. Bandy, 1951. Rocks and Minerals, vol. 26, p. 521. A variety of stibiotantalite ($Sb(Ta,Nb)O_4$) containing Bi_2O_3 3·98 %, from Mozambique. [M.A. **11**–477.]

Suomite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 11 (suomita). Tantalic ochre (tantalochra of A. E. Nordensiöld, 1855) believed to be Ta_2O_5 as a brown coating on crystals of tantalite from Finland = Suomi.

Taaffeite. B. W. Anderson, 1951. Gemmologist, London, vol. 20, p. 76. B. W. Anderson, C. J. Payne, and G. F. Claringbull, Min. Mag., 1951, vol. 29, p. 765. B. W. Anderson, Gemmologist, 1952, vol. 21, p. 23 (pronounced "tarfite"; other names provisionally suggested, "bemagalite" and "berinel", refer to the chemical composition and to the relation to spinel). $BeMgAl_2O_8$, hexagonal. Known only as two small faceted gemstones resembling mauve-coloured spinel. Named after Count Edward Charles Richard Taaffe (1898-) of Dublin, who first detected it. [M.A. **11**–309, 369, 485.]

Tablite. Bull. Soc. Franç. Min. Crist., 1950, vol. 73, p. 151. 'Un antimonioarséniate de cuivre et de cobalt d'un gisement métallifère d'Afrique du Sud'. *See* Allevardite and tabulite.

Tabulite. E. Lemoine, 1950. Bull. Soc. Franç. Min. Crist., vol. 73, p. 146. Alternative name suggested for allevardite (q.v.). Named from the locality, La Table (mountain) in Savoie, near Allevard in Isère.

Tangenite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 10 (tangenita). A betafite-like mineral containing TiO_2 32·27–35·05 % from Tangen near Kragero, Norway, described by H. Bjørlykke, 1931 [M.A. **5**–425].

Tellite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 8 (tellita). A single steel-grey crystal of unknown composition, from Binn, Switzerland, described crystallographically (triclinic?) by G. F. H. Smith (Min. Mag. **19** 40). Named after the Swiss national hero William Tell.

Teluroselenio. F. Pardillo, 1947. Tratado de mineralogía, translation of 12th edit. of F. Klockmann and P. Ramdohr, Barcelona, p. 318; G. Gagarin and J. R. Cuomo, 1949, loc. cit., 1949, p. 6. Spanish form of selen-tellurium. *See* Hondurasite.

Tieilite. G. Yamaguchi, 1944. [Journ. Japanese Ceramic Assoc., vol. 52, p. 6]; Chem. Abstr., 1951, vol. 45, col. 7925. Al_2TiO_5, orthorhombic, isomorphous with pseudobrookite (Fe_2TiO_5); prepared artificially, and present in abrasives. [M.A. **11**–415.]

Tinkalite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 12 (tinkalita). Synonym of tincal = borax.

Titanelpidite. A. N. Winchell, 1951. Optical mineralogy, pt. 2, 4th edit., p. 455. Variant of titano-elpidite (11th List).

Torreyite. J. Prewitt-Hopkins, 1949. Amer. Min., vol. 34, p. 589. $(Mn,Mg,Zn)_8(SO_4)(OH)_{14}.4H_2O$, monoclinic, from Sterling Hill, New Jersey. Previously named δ-mooreite, but giving an X-ray pattern distinct from that of mooreite (12th List). Named after John Torrey (1796–1873), American botanist, chemist, and mineralogist. Not the torrelite of T. Thomson, 1836, or of J. Renwick, 1824. [M.A. **11**–9.]

Tschirwinskite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 13 (tschirwinskita). Hydrous ferric phosphate, $Fe_2O_3.P_2O_5.2\frac{1}{2}H_2O$, from Kerch, Crimea, described in 1904 by Petr Nikolaevich Chirvinsky Петр Николаевич Чирвинский (1880–). Not the chirvinskite of N. K. Platonov 1941 (17th List).

Tungsten-powellite. O. H. Ödman, 1950. Årsbok Sveriges Geol. Undersök., vol. 44, no. 2, p. 23. A variety of powellite ($CaMoO_4$) containing WO_3 9·6–14·0 %. [M.A. **11**–473.]

Umanguita. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 15. Variant of umangite to accord with Spanish pronunciation. Named from the locality, Sierra de Umango, La Rioja, Argentina.

Villiersite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 14 (villiersita). A nickel-bearing silicate (NiO 30·6 %), $(Ni,Mg,Fe,Co)_7Si_8O_{22}(OH)_2$ resembling talc, described by F. C. Partridge from Bon Accord, Transvaal [M.A. **9**–189]. Named after Dr. J. E. de Villiers of the Geological Survey of South Africa, who prepared the posthumous paper for publication.

Wherryite. J. J. Fahey, E. B. Daggett, and S. G. Gordon, 1950. Amer. Min., vol. 35, p. 93. $PbCO_3.2PbSO_4.Pb(Cl,OH)_2.CuO$. Pale green, finely granular, optically biaxial, from Mammoth mine, Arizona. Named after Edgar Theodore Wherry (1885–), professor of plant ecology, University of Pennsylvania. [M.A. **11**–127.]

Whitmanite. J. Murdoch, 1948. Progr. & Abstr. Min. Soc. Amer., 1948, p. 11. A preliminary spectroscopic analysis suggested Mg-Mn titanate. A later chemical analysis (Amer. Min., 1949, vol. 34, p. 835 [M.A. **11**–243]) showed only 0·4 % MnO, identifying the supposed new mineral with geikeilite. Named after the late Alfred Russell Whitman, of the University of California at Los Angeles.

Wilkinite. S. D. Wells, Paper, New York, 1920, vol. 27, no. 14, p. 19 (wilkinite); P. F. Kerr and P. K. Hamilton, Glossary of clay mineral names, New York, 1949, p. 68 (wilkonite). Trade-name for a highly colloidal bentonitic clay ('jelly rock') used in paper making.

Wolfeite. C. Frondel, 1949. Amer. Min., vol. 34, p. 692. $(Fe'',Mn'')_2(PO_4)(OH)$, with Fe > Mn, monoclinic; previously included in triploidite $(Mn'',Fe'')_2(PO_4)(OH)$. Named after Prof. Caleb Wroe Wolfe, of Boston University, Massachusetts, who first noticed the mineral (as triploidite) at North Groton, New Hampshire. [M.A. **11**–9.]

Wretbladite. G. Gagarin and J. R. Cuomo, 1949, loc. cit., p. 5 (wretbladita). The compound AsSb in the system As–Sb. To replace the name stibarsen = allemontite II (P. E. Wretblad, 1941, 16th List) which has been given in Spanish as arsenoestibio (q.v.). Named after P. Erik Wretblad of Fagersta, Sweden.

Yttrium-orthite. J. W. Frondel and M. Fleischer, 1950. U.S. Geol. Surv. Circular 74, p. 10 (yttrium orthite), p. 20 (Yttriumorthite). Synonym of yttro-orthite (13th List).

Yttroalumite. H. S. Yoder and M. L. Keith, 1951. Amer. Min., vol. 36, p. 522. The high-temperature tetragonal modification of $Yt_3Al_2(AlO_4)_3$. *See* Yttrogarnet. [M.A. **11**–364.]

Yttrogarnet. H. S. Yoder and M. L. Keith, 1951. Amer. Min., vol. 36, p. 522. Artificial $3Yt_2O_3.5Al_2O_3 = Yt_3Al_2(AlO_4)_3$ forming a con-

tinuous series of cubic mixed crystals with spessartine ($Mn_3Al_2(SiO_4)_3$). It is presumably present in natural yttrium-bearing spessartine (yttergarnet, ytter-garnet, yttriogarnet, emildine, erinadine). At about 1970° C. it is transformed to yttroalumite (q.v.). [M.A. **11**–364.]

Yttrotungstite. E. H. Beard, 1950. Colonial Geol. & Min. Resources, London, vol. 1, p. 51. To replace the name 'thorotungstite' [11th List] for a Malay mineral which contains rare-earths (Yt, Ce) and no Th. [M.A. **11**–189.]

Zinc-fauserite. L. Tokody, 1949. Földtani Közlöny, Budapest, vol. 79, p. 68 (Cinkfauserit, Hungarian), p. 78 (Zinkfauserint, misprint for Zinkfauserit, German). $(Mn,Zn,Mg)SO_4.5H_2O$, orthorhombic. A variety of fauserite containing ZnO 5·08 %, from Felsőbánya. [M.A. **11**–10.]

Zinc-saponite. C. E. Marshall, 1949. The colloidal chemistry of silicate minerals, p. 62 (zinc saponite). Syn. of sauconite [M.A. **10**–27].

SYSTEMATIC CLASSIFICATION OF NEW MINERALS[1]

Elements

Garibaldite, β-S, II.
Aurostibite, $AuSb_2$, VII.
Allargentum, Ag, Sb, VI.

Sulphides, etc.

Hurlbutite, Zn_4S_4, VI.
Fleischerite, Zn_6S_6, VI.
Buergerite, $Zn_{15}S_{15}$, V.
Eskebornite, (Fe,Cu)Se, VI.
Shandite, $Ni_3Pb_2S_2$, V.
Montesite, $PbSn_4S_5$, III.
Robinsonite, $7PbS.6Sb_2S_3$, I.

Haloids

Hoppingite, HgI_2, VII.
Belyankite, $Ca_3Al_2F_{12}.4H_2O$, II.
Boldyrevite, $NaCaMgAl_3F_{14}.4H_2O$, VII.
Bararite, $(NH_4)_2SiF_6$, VI.
Camermanite, K_2SiF_6, VI.

Oxides (Titanates, Aluminates)

Ferropericlase, VII.
Anosovite, Ti_3O_5, III.
Tieilcite, Al_2TiO_5, III.
Priderite, $(K,Ba)_{1\cdot3}(Ti,Fe''')_8O_{16}$, IV.
Taaffeite, $BeMgAl_2O_8$, VI.
Magnalumoxide, $(Mg,Fe)_5(Al,Fe)_{18}O_{32}$, VII.

Carbonate

Capillitite, $(Mn,Zn,Fe)CO_3$, V.

Nitrate

Ammonia-nitre, $(NH_4)NO_3$, III.

Borate

Sinhalite, $MgAlBO_4$, III.

Sulphates

Miltonite, $CaSO_4.\frac{1}{2}H_2O$, V.
Sanderite, $MgSO_4.2H_2O$.
Leonhardtite, $MgSO_4.4H_2O$.
Allenite (pentahydrite), $MgSO_4.5H_2O$. I.
Kellerite, $(Mg,Cu)SO_4.5H_2O$, I.
Comstockite, $(Mg,Cu,Zn)SO_4.5H_2O$, I.
Matteuccite, $NaHSO_4.H_2O$, II.
Manganleonite $K_2Mn(SO_4)_2.4H_2O$, II.
Metabasaluminite, $Al_4SO_4(OH)_{10}$.
Ktenasite, $3(Cu,Zn)O.SO_3.4H_2O$, II.
Torreyite, $(Mn,Mg,Zn)_8SO_4(OH)_{14}.4H_2O$, II.

[1] Only selected names given in the preceding alphabetical list are here included. Following A. E. H. Tutton (Crystallography, 1911, 1922) the crystal systems are indicated as: I triclinic, II monoclinic, III orthorhombic, IV tetragonal, V trigonal, VI hexagonal, VII cubic.

Wherryite,
$2PbSO_4.PbCO_3.Pb(Cl,OH)_2.CuO$.
Meta-uranopilite,
$(UO_2)_6(SO_4)(OH)_{10}.5H_2O$.

TUNGSTATE

Yttrotungstite.

PHOSPHATES, ETC.

Hurlbutite, $CaBe_2(PO_4)_2$, III.
Hühnerkobelite,
$(Na_2,Ca)(Fe'',Mn'')_2(PO_4)_2$, III.
Magniophilite, $(Mn,Fe,Mg)_3(PO_4)_2$.
Phosphoscorodite, $Fe(As,P)O_4.2H_2O$, III.
Mangankoninckite, $(Fe,Mn)PO_4.3H_2O$.
Wolfeite, $(Fe'',Mn'')_2PO_4(OH)$, II.
Frondelite, $(Mn'',Fe'')Fe'''_4(PO_4)_3(OH)_5$, III.
Rockbridgeite,
$(Fe'',Mn'')Fe'''_4(PO_4)_3(OH)_5$, III.
Laubmannite,
$(Fe'',Mn'',Ca)_3Fe'''_6(PO_4)_4(OH)_{12}$, III?
Kryzhanovskite,
$MnFe'''_2(PO_4)_2(OH)_2.H_2O$, II.
Iron-lazulite, $(Fe'',Fe''')_7(PO_4)_4(OH)_4$, IV.
Scholzite, $Ca_3Zn(OH)_2(PO_4)_2.H_2O$, II.
Cobalt-cabrerite,
$(Co,Mg)_3(AsO_4)_2.8H_2O$, II.
Nickel-cabrerite,
$(Ni,Mg)_3(AsO_4)_2.8H_2O$, II.
Sabugalite, $HAl(UO_2)(PO_4)_2.16H_2O$, IV.
Nováčekite, $Mg(UO_2)(AsO_4)_2.9H_2O$, IV.
Metazeunerite, $Cu(UO_2)(AsO_4)_2.8H_2O$, IV.
Metasaléeite, $Mg(UO_2)PO_4.8H_2O$, IV.

VANADATES

Hummerite, hyd. Mg, I.
Montroseite,
$2FeO.V_2O_3.7V_2O_4.4H_2O$, III.

ANTIMONATE

Byströmite, $MgSb_2(O,OH)_6$, IV.

TITANATES (with Nb, &c.)

Kobeite, $(Yt,Fe,U)(Ti,Nb,Ta)_2(O.OH)_6$.
Belyankinite, $2CaO.12TiO_2.\frac{1}{2}Nb_2O_5.ZrO_2.SiO_2.28H_2O$.

SILICATES

Huttonite, $ThSiO_4$, II.
Dalyite, $K_2ZrSi_6O_{15}$, I.
Iron-åkermanite, $2CaO.FeO.2SiO_2$, IV.
Hanléite, $Mg_3Cr_2(SiO_4)_3$, VII.
Yttrogarnet, $Yt_3Al_2(AlO_4)_3$, VII.
Miserite, $KCa_4Si_5O_{13}(OH)_3$, III?
Ferrocarpholite, $H_4FeAl_2Si_2O_{10}$, III.
Gunnbjarnite, $3(Mg,Ca,Fe)O.(Fe,Al)_2O_3.6SiO_2.3H_2O$, III.
Lombaardite,
$Ca_{10}(Fe,Mg)_5(Al,Fe)_{27}Si_{18}O_{89}(OH)_5$, II.
Perrierite, Si, Ti, Yt, Ce, &c., II.

HYDROCARBON

Fringelite.

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